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Communication between infant boys and their mothers with ADHD symptoms

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Abstract

Aim: This preliminary longitudinal study examined timing features and type of interaction between infant boys and their mothers with attention deficit hyperactivity disorder (ADHD) symptoms

Method: Ten infants and their mothers with ADHD symptoms and 10 control dyads were video recorded at home during free play interactions when infants were 2-, 4-, 6-, and 9-month old. Microanalysis of the video recordings was carried out to assess synchronization, turn-taking, and type of interaction. Infants' temperament was also assessed

Results: ADHD dyads showed shorter synchronization at 2 months and shorter duration of Joint Attention. Partial least squares regression analysis revealed that infant's ability for Joint Attention is predicted mainly by duration of maternal behavior as well as by earlier forms of communication, that is, *protoconversations*.

Conclusion: The data from our preliminary study suggest that mothers with ADHD symptoms may have difficulties maintaining their behavior for enough time possibly due to the core symptoms of the disorder, that is, inattention, hyperactivity, and impulsivity. This maternal deficit seems to affect temporal coordination with their infants and maybe the development of more complex forms of interaction. Clinical implications of these findings are also discussed.

KEYWORDS
ADHD, early intervention, intersubjectivity, joint attention, synchronization

1 | INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that develops during childhood and insists to adulthood in 50–80% of cases (Barkley et al., 2006; Faraone, Biederman, & Mick, 2006). According to DSM-5 (APA, 2013), the core symptoms of the disorder include developmentally inappropriate levels of hyperactivity, impulsivity, and inattention, although ADHD symptoms tend to change over time with waning hyperactivity and impulsivity, but rather persisting inattention. In adults, ADHD symptoms are associated with significant impairments across several domains such as academic achievement, occupational attainment, and interpersonal relationships. Adults with ADHD show a higher divorce rate, have more interpersonal conflicts, suffer from emotional dysregulation, and report more problems in organizing and planning activities as well as more drug and alcohol problems (Barkley, Murphy, & Fischer, 2008; Mannuzza et al., 2011).

Although the prevalence of ADHD is higher among male children, in adulthood prevalence appears to be similar in males and females (Faraone & Biederman, 2005; Kessler et al., 2006). Moreover, early ADHD symptoms robustly predict manifestation of other disorders later in life (Chronis-Tuscano et al., 2010; Franklin et al., 2017). In women, early onset of ADHD may cause depression or anxiety. Given that in many cases specialists pay more attention to depression, anxiety, and low self-esteem symptoms, these women may be misdiagnosed (Quinn, 2005; Semple, Mash, Ninowski, & Benzies, 2011). Women with ADHD often develop postpartum depression, possibly because they are excessively worried about their ability to respond to their infants and they feel less effective (Semple et al., 2011), whereas their expectations about parental role are lower (Banks, Ninowski, Mash, & Semple, 2008; Barkley, Anastopoulos, Guevremont, & Fletcher, 1992; Watkins & Mash, 2009).

Research on how maternal ADHD influences child development is extremely important given the high heritability of the disorder. It is noteworthy that well over half of adults with ADHD have at least one child with the disorder, and a similar percentage also holds for children with ADHD having a parent with the disorder (Banks et al., 2008; Kessler et al., 2006; Minde et al., 2003). It is likely that mothers who have deficient regulation skills may be less able to support communicative interaction with their child, and thus less able to promote the development of such skills in their child. On the other hand, mothers with ADHD may be more in synchrony with a child's preference for more vivid activities, thus attenuating and even buffering any child problems related to ADHD (Johnston, Mash, Miller, & Ninowski, 2012).

However, relatively few studies have examined the impact of ADHD symptoms on parenting. Johnston et al. (2012) attribute this fact to the lack of a theoretical or conceptual framework to guide such work and review studies that explain deficits in parenting with ADHD as a result of executive dysfunctions. In particular, the authors suggest that deficits in cool executive functions, such as working memory, inhibitory control, and planning as well as deficits in self-regulation of behavior and emotion, may cause inadequate monitoring, poor parental planning or problem-solving, insufficient or unclear guidance, reduced sense of parenting efficacy, and parental stress. Relevant studies examining mainly preschool and school aged children confirm these assumptions. Specifically, it was shown that mothers with ADHD symptoms have difficulty setting limits and appropriate rules, leading to chaotic home environment and inconsistent discipline (Chen & Johnston, 2007; Mokrova, O'Brien, Calkins, & Keane, 2010). In addition, they were more negative, reactive, or even hostile and they could not respond appropriately to their child's needs for attention (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993; Ellis & Nigg, 2009; Gershy & Gray, 2020). Furthermore, it was demonstrated that although mothers with ADHD could find the same number of solutions for their child's behavior problems, the quality and organization was inferior compared to mothers without ADHD (Murray & Johnston, 2006).

Key Findings

1. Infant boys and their mothers with ADHD symptoms are less synchronized during communicative interactions from 2 to 9 months, compared to the control group.
2. Infant boys and their mothers with ADHD symptoms exhibit shorter interpersonal interaction and joint attention episodes compared to the control group.
3. Synchronization as well as type of interaction are predicted by duration of maternal behavior.

Research on the influence of maternal ADHD symptoms on infants may further highlight the developmental trajectories that lead to ADHD and comorbid disorders, or to the avoidance of such outcomes among the offspring. Nevertheless, studies focusing on this issue are even more rare. Barkley (2006) notes that mothers with ADHD have difficulties in understanding the infant's gaze as well as her facial and vocal expressions and movements. Also, they may play with an object that is not interesting for the infant anymore, switch activities too fast, or present excessive stimuli to the infant. In a pioneering case study, Daly and Fritsch (1995) observed a 2-month-old male infant who was hospitalized because of low birth weight. However, the problem turned out to be psychological, not medical. Evaluation led to the diagnosis of residual attention deficit disorder in the mother. Inattention and impulsivity hampered mother's ability to feed the child. With the appropriate treatment and intervention, mother–infant interaction and communication was improved (Daly & Fritsch, 1995).

Landau et al. (2009) measured interactions between parents and their 7-month-old male infants who were designated as high- and low-risk for ADHD based on the level of ADHD symptomatology in their fathers. Parent–infant interaction took place in an experimental setting in three conditions: (a) warm-up, (b) face-to-face interaction without toys, and (c) face-to-face interaction with toys. Aspects of parent–infant interaction were assessed by coding infant behavior and parental responsivity, focusing especially on parental response in cases the infant needs help. The authors report no differences between the two

groups as regards in infant negative affect, bids for attention, need for help, and physiological events. Nevertheless, compared to the low-risk group, both fathers and mothers in the high-risk group were observed as less responsive in their parenting during face-to-face interactions with the infant, particularly in terms of responding intensively to infant negative emotions and distress.

In a cross-sectional study, Semple et al. (2011) investigated how mothers' ADHD symptoms affect their relationship with their 3- to 8-month-old infants. Forty mother–infant dyads were video recorded in one visit during feeding, a structured task, and free play. Interactions were coded using the Qualitative Ratings for Parent–Child Interactions (QRPCI), which measures maternal sensitivity, intrusiveness, and negative affect as well as infant positive and negative affect and activity level. Results showed that after controlling for maternal ratings of infant activity, maternal ADHD symptoms were related to less maternal sensitivity. In turn, less maternal sensitivity and more negative regard were related to more infant negative affect.

Thus far, relevant studies provide valuable data on the effects of mother's ADHD on her responsivity to the infant, especially infant's bids for help and negative affect at specific ages. The present study aims to expand this research field by examining longitudinally aspects of mother–infant interaction in a naturalistic setting in the framework of the Intersubjectivity Theory.

According to the Intersubjectivity Theory (Trevarthen, 1980, 1993, 1998; Trevarthen & Aitken, 2001), mother–infant interaction emerges from innate motives for understanding and responding to the physical and social environment. As infants grow older, the fundamental motives for interpersonal interaction and for exploration of the inanimate environment are combined and more complex forms of social engagement appear. Thus, infants gradually progress from *Primary Intersubjectivity* to *Secondary Intersubjectivity* (Fogel & DeKoeyer-Laros, 2007; Trevarthen, 1993). *Primary Intersubjectivity* is manifested around 2 months and involves direct interpersonal attention and mutual attunement. Infants at this age are sensitive to the reciprocity of emotions and capable of recognizing communicativeness and its absence or appropriateness. At 6 months, remarkable changes in self-awareness are observed, and infants become capable of showing off as well as expressing shyness and humor (Reddy, 2008). *Secondary Intersubjectivity* appears around 9 months and refers to the infant's ability to share intentions, interests, and emotions with a partner in joint exploration and use of objects (Reddy, 2008; Trevarthen & Hubley, 1978). The most salient manifestation of *Secondary Intersubjectivity* is joint attention. Joint attention is the coordination of attention between social partners and objects in order to communicate an experience or to achieve a common goal (Tomasello, 1995). This form of cooperation constitutes prerequisite for more advanced social skills, cognitive development, language development as well as the inclusion in the culture (Tomasello & Carpenter, 2007; Trevarthen, 1998).

Mother–infant interaction is organized in a time frame that is mutually regulated by both partners, whereas its success and complexity depend on the degree of temporal coordination between them (Malloch & Trevarthen, 2009; Schirmer, Meck, & Penney, 2016). As one partner takes the initiative and the other responds, interaction begins and coordination is achieved through rhythmic patterns of behavior manifested in different modalities, that is, gestures, facial expressions, and vocalizations (Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001). Mother's role in the formation of this time framework is crucial. Maternal expressions of any modality are characterized by rhythmic patterns observed in many different cultures. These rhythmic patterns are modified as infants grow older to adapt to newly developed abilities. Experimental studies show that infants are endowed with an innate ability to perceive and react in accordance with these stimulating maternal communicative signals even before birth (Malloch & Trevarthen, 2009). Moreover, infants are highly sensitive to the perturbation of these regular predictable maternal behaviors. In cases maternal behavior does not exhibit predictable timing characteristics such as in experiments of simulated perturbation (Murray & Trevarthen, 1985; Tronick, Als, & Adamson, 1979) or when the mother suffers from anxiety (Murray, Cooper, Creswell, Schofield, & Sack, 2007) or depression (Apter, Devouche, & Gratier, 2011), infants express excessive frustration and the dyad cannot maintain sustained engagement. Repeated failures of mother–infant dyads to establish interpersonal interaction have long-term negative effects on child's social and cognitive development (Murray & Cooper, 1997).

Considering the above remarks, it was designed a small-scale preliminary longitudinal study aiming to investigate timing characteristics and their effect on the type of interaction (i.e., interpersonal interaction, humor, and joint attention) between infants and their mothers with ADHD symptoms.

The following hypotheses were formed:

- ADHD dyads would synchronize their behavior for less time compared to the control group.
- Duration of maternal behavior in the ADHD group would be shorter compared to the control group.
- Interpersonal interaction, humor, and joint attention would be limited in ADHD dyads compared to control dyads.
- Interpersonal interaction, humor, and joint attention may be related to duration of maternal and infant behavior as well as their synchronization.

- Interpersonal interaction that develops earlier may be related to joint attention that develops later.

2 | METHODS

2.1 | Participants

Twenty mothers and infant boys participated in this study. Dyads were examined longitudinally from 2 to 9 months of infants' age. Participants were recruited from local maternity clinics 2 weeks before delivery and came from middle-class Greek-speaking families. Maternity clinics can be utilized by population with either public or private health insurance. Mothers were assigned in two groups, the ADHD group and the control group, according to the results in the Adult ADHD Self-Report Scale Symptom Checklist (ASRS v1.1) and the Diagnostic Interview for ADHD in Adults (DIVA). Recruitment is described in Section 2.3. None of the mothers had a previous clinical diagnosis of ADHD or another disorder. However, all mothers were able to easily recognize the inattention and hyperactivity/impulsivity problems from childhood to adult life. No screening tests were carried out for comorbid diagnoses because the recognition of symptoms in childhood suggests that ADHD may have occurred first in these women, even when comorbidities followed. Mothers' age in the ADHD group ranged from 27 to 38 years (mean age = 32.6 years, $SD = 3.5$), whereas mothers' age in the control group ranged from 26 to 41 years (mean age = 31.8 years, $SD = 4.1$). This difference was not statistically significant ($t = 0.39$, $P = .701$, $\eta^2 = 0.023$). In the ADHD group, six mothers had university education, three had technological education, and one had compulsory education, whereas in the control group eight mothers had university education, one had technological education, and one had compulsory education. Chi square test showed that mothers did not differ significantly in educational level ($\chi^2 = 0.67$, $P = .716$).

All infants in the present sample were full-term with high Apgar scores and no perinatal complications. Also, no group differences were observed in dimensions of infant temperament as assessed at 9 months with the Infant Behavior Questionnaire—Revised (IBQ-R) (Table 1).

TABLE 1 Group differences in the three broad scales of the IBQ-R

	ADHD	TYPICALLY DEVELPING (TD)	*t*	*P*-value
Positive affect	32.2 (4.64)	32.9 (3.65)	−0.3	.759
Negative affect	17.4 (1.97)	16.3 (2.41)	0.9	.343
Orienting regulation	21.9 (2.08)	20.5 (1.67)	1.5	.163

None of the mothers or the infants exhibited severe sensory or motor deficiencies or had been hospitalized.

2.2 | Materials

2.2.1 | Adult ADHD Self-Report Scale Symptom Checklist

ASRS was designed by the World Health Organization in order to detect ADHD symptoms in adults. ASRS consists of 18 questions divided in two parts. The first part includes six questions regarding inattention, whereas the second part includes 12 questions regarding hyperactivity and impulsivity. The answers are organized on a 5-point Likert scale (0 = *never*, 1 = *rarely*, 2 = *sometimes*, 3 = *often*, and 4 = *very often*). High scores are indicated in bold boxes. In part A, a person is highly likely to have inattention symptoms if he/she has high scores in at least four items. In part B, a person is highly likely to have hyperactivity/impulsivity symptoms if he/she has high scores in at least seven items. The ASRS is standardized in Greek and shows moderate to high reliability and validity (Kessler et al., 2005).

2.2.2 | Diagnostic Interview for ADHD in Adults

Given that the ASRS scale only detects symptoms of ADHD but does not offer a diagnosis of the disorder, the Diagnostic Interview for ADHD in Adults (DIVA) was also used for that purpose. The DIVA was created in Holland and is found to successfully discriminate individuals with ADHD symptoms from individuals without ADHD symptoms, with sensitivity 90% and specificity 72% (Pettersson, Söderström, & Nilsson, 2018; Ramos-Quiroga et al., 2016). The DIVA consists of three parts and includes questions according to the DSM-IV criteria for ADHD, from childhood to adult life. The first part includes questions relevant to the inattention criteria, the second part is relative to hyperactivity and impulsivity criteria, and the third part detects the age of onset of ADHD symptoms in total. Six or more symptoms in every group of criteria or in total represent an ADHD diagnosis.

2.2.3 | Infant Behavior Questionnaire—Revised

IBQ-R is a revised form of the Child Behavior Questionnaire (Rothbart, 1981) and constitutes a valid and reliable measure of temperament in infants aged 3–12 months old.

It comprises 91 questions and 14 scales that assess the following dimensions: (a) activity level, (b) distress to limitations, (c) fear, (d) duration of orienting, (e) smiling and laughter, (f) high pleasure, (g) low pleasure, (h) soothability, (i) falling reactivity/rate of recovery from distress, (j) cuddliness, (k) perceptual sensitivity, (l) sadness, (m) approach, and (n) vocal reactivity. The 14 scales of the IBQ-R are grouped in three broad scales, namely, positive affect, negative affect, and orienting regulation. The IBQ-R was completed by the mothers when infants were 9-month old.

2.3 | Procedure

In the first place, 100 mothers completed the ASRS 2 weeks before delivery. According to the results, 18 mothers were found to exhibit ADHD symptoms. Three of them had delivered girls and 15 had delivered boys. The researcher explained to these mothers about the longitudinal study on mother–infant communication and 10 of them, incidentally only ones that had delivered boys, accepted to participate in the study. This group was matched with 10 mothers without ADHD symptoms randomly selected from a pool of 39 mothers who also accepted to participate in the longitudinal study. Then the DIVA interview was conducted to mothers of both groups and the results confirmed the classification of the ASRS. Written parental permission was obtained before the outset of the longitudinal study.

Families were visited at their home when infants were 2-, 4-, 6-, and 9-month old two times a week per age and each time were video recorded while playing with their mother. The day and the time of the visit were arranged to be convenient for the family and not to interfere with the infant's primary care (i.e., feeding or sleeping). Mothers were asked to interact with their infants as they would normally do. At 2 and 4 months, dyads were filmed for 15 min, at 6 months for 20 min, and at 9 months for 30 min.

2.4 | Coding

The coding system for the behavior analysis was based on previous schemes (Laing et al., 2002; Papaeliou & Trevarthen, 2006; Papaeliou, Sakellaki, & Papoulidi, 2019) and was further expanded for an inductive analysis of the video recordings. Initiation for interaction was defined as any overt attempt by either the mother or the infant to commence an interaction. Response was defined as any verbal or gestural behavior directed toward the initiating partner. No response was coded when there was no apparent behavioral response to the initiator within 1-s latency (Dominguez, Devouche, Apter, & Gratier, 2016; Jaffe et al., 2001). The coding system was intended to be concise and not redundant and to describe overt behaviors (Papaeliou et al., 2019). In order to investigate mother–infant interaction, the following parameters were measured:

2.4.1 | Time parameters

Following are the time parameters:

1. Synchronization (SYN): the time frame in which mother and infant are involved in the same activity. It begins when both partners take over the same activity and terminates when one partner stops acting on this theme.
2. Duration of Maternal Behavior (DUR_M): the duration of mother's behavior during synchronization.
3. Duration of Infant Behavior (DUR_I): the duration of infant's behavior during synchronization.
4. Overlap (OVRLP): the duration that partners' behaviors co-occur simultaneously.
5. Latency (LAT): the duration between the end of one partner's behavior and the beginning of the other partner's behavior.

2.4.2 | Types of interaction

Four types of interaction were defined based on behaviors that reveal the degree of involvement between partners:

1. Independent Play (INDP): Mother and infant focus on different themes or one of them is not focusing on any theme.
2. Interpersonal Interaction (IPI): Mother and infant communicate without using any toys or they do not focus in any theme beyond the dyad.
3. Humor (HUM): Each partner responds positively to the other's teasing behavior.
4. Joint Attention (JA): Mother and infant act cooperatively to complete a common goal or one partner attempts to attract the other's attention to one's own interest by pointing, showing, or offering an object spontaneously or one partner follows the other's interest by following the other's gaze or pointing.

Moreover, in each synchronization episode it was noted who took the initiative and who terminated the interaction.

For the microanalysis recordings of the two visits were used. Microanalysis permits a detailed analysis of

behaviors, capturing subtle qualitative differences in social engagement. For the microanalysis of the video recordings, the EUDICO Linguistic Annotator (ELAN) was used. ELAN is a professional tool for the creation of complex annotations on video and audio resources, developed at the Max Planck Institute for Psycholinguistics.

From each play session for each child, a continuous footage was analyzed and the duration of each codified behavior per minute was noted. The first 5 min of each session were not analyzed to counter adaptation effects. Times where play was interrupted by irrelevant stimuli (e.g., bell ringing) or where it was difficult to see clearly what the mother and the infant were doing were excluded from the analysis.

Behaviors were coded on a split-second basis. Milliseconds was the unit of analysis that was considered most appropriate for the present data. At an initial level, behaviors were coded independently for the mother and the infant on a frame-by-frame basis and then their behaviors were combined in order to assess the type of interaction. Two independent researchers blind to group made the coding. Interrater and intrarater reliability was calculated for three ADHD dyads and three typically developing (TD) dyads (approximately 30% of the sample) for each behavior category and was found to be very high. For interrater reliability, Cohen's kappa ranged from .77 to .87 and for intrarater reliability kappa ranged from .78 to .91.

2.5 | Statistical analysis

The observed duration of each time parameter was divided by the length of observation in each age. The effects of age and the disorder were calculated using Mixed Effects Models (MEM). MEM is particularly useful in settings where repeated measurements are made on the same statistical units, as is the case in longitudinal studies (Howell, 1987).

Also, the present study examined the prediction of types of interaction (dependent variables) from certain time parameters (independent variables) using the Partial Least Squares (PLS) regression. PLS has been used in a wide range of fields and has become a popular method because of its several advantages over multiple regression: (a) it is a powerful statistical method designed to cope with the problems of multicollinearity between the independent variables, (b) it produces useful and robust equations with small sample sizes, and (c) predictions with PLS models tend to be more accurate than multiple regression models. In the PLS regression, the *Q*š cumulated index measures the predictive quality of the model and the cumulated *R*š*Y* and *R*š*X* correspond to the correlations between independent (*X*) and dependent (*Y*) variables. Values close to 1 indicate that the regression model is reliable. Variance Importance in Projection (VIP) scores give an estimate of the contribution of each independent variable in explaining the dependent variable (Vinzi, Chin, Henseler, & Wang, 2010).

3 | RESULTS

3.1 | Time parameters

Time parameters, that is, synchronization, duration of maternal behavior, duration of infant behavior, overlap, and latency, were introduced in the MEM as dependent variables, and group and age as independent variables. Results demonstrated significant interaction group × age effect only for overlap ($F = 2.9$, $P = .040$), but not for synchronization ($F = 0.6$, $P = .629$), duration of maternal behavior ($F = 0.9$, $P = .442$), duration of infant behavior ($F = 0.2$, $P = .920$), and latency ($F = 0.2$, $P = .906$). Moreover, no significant main effect of age was observed for duration of maternal behavior ($F = 1.4$, $P = .247$), duration of infant behavior ($F = 1.8$, $P = .151$), and latency ($F = 2.4$, $P = .078$). However, significant main effect of age was observed for synchronization ($F = 3.1$, $P = .037$) and overlap ($F = 7.9$, $P < .001$). Pairwise comparisons showed a significant increase of synchronization from 2 to 9 months and a significant decrease of overlap from 2 to 4 months. On the other hand, significant group differences were observed for synchronization ($F = 28.2$, $P < .001$), duration of maternal behavior ($F = 18.1$, $P < .001$), and duration of infant behavior ($F = 6.2$, $P = .016$), but not for overlap ($F = 1.5$, $P = .226$) or latency ($F = 0.1$, $P = .729$). Specifically, the ADHD group showed significantly shorter synchronization (mean = 6.4 vs. 12.9, $SD = 4.9$ vs. 5.0) (Figure 1), duration of maternal behavior, and duration of infant behavior, compared to the TD group (Table 2).

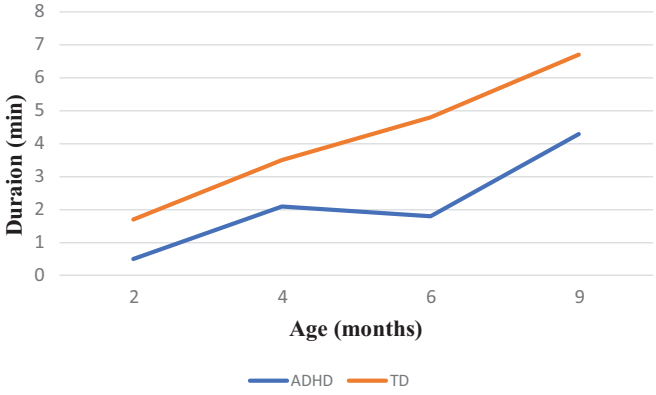

FIGURE 1 Group differences in synchronization by age

TABLE 2 Differences between mothers and infants in duration of behavior

	Mother		Infant				
	Mean	*SD*	Mean	*SD*	*t*	*P*-value	η^2
ADHD	6.7	4.7	6.3	4.9	0.6	0.519	0.078
TD	11.8	4.7	9.7	5.4	2.3	0.030	0.411

TABLE 3 Differences between mother and infant initiation and termination

	Mothers		Infants				
Initiation	Mean	*SD*	Mean	*SD*	*t*	*P*-value	η^2
ADHD	10.2	7.1	5.1	4.1	4.8	<.001	0.875
TD	10.9	8.3	6.2	4.4	3.8	.001	0.714
Termination							
ADHD	4.0	3.1	7.8	5.7	−3.2	.004	0.867
TD	4.0	3.6	9.2	5.6	−3.9	<.001	0.984

Differences between duration of maternal behavior and duration of infant behavior in each group were calculated with paired samples *t*-tests. Results showed that in the ADHD group there was no significant difference between duration of maternal behavior and duration of infant behavior. On the contrary, in the control group duration of maternal behavior was significantly longer compared to duration of infant behavior (Table 2).

3.2 | Turn-taking

Infant and mother initiation and termination were investigated as parameters of turn-taking. The results of MEM showed no significant interaction group × age effect for either mother initiation ($F = 0.4$, $P = .780$) or infant initiation ($F = 0.5$, $P = .663$). Moreover, no main effect of group was observed for either mother initiation ($F = 0.3$, $P = .576$) or infant initiation ($F = 1.7$, $P = .196$). However, significant main effect of age was observed for mother initiation ($F = 28.7$, $P < .001$) and infant initiation ($F = 18.7$, $P < .001$). Pairwise comparisons showed a similar pattern of increase in initiatives in both mothers and infants from 2 to 6 months and from 6 to 9 months. Also, paired samples *t*-tests were carried out to investigate differences between mother and infant initiation in each group. Results showed that in both groups mothers initiated significantly more interactions than infants (Table 3).

As regards termination, no significant interaction group × age effect for either mother termination ($F = 0.5$, $P = .671$) or infant termination ($F = 0.9$, $P = .432$) was found. Moreover, no main effect of group was observed for either mother termination ($F < 0.1$, $P = .962$) or infant termination ($F = 1.4$, $P = .245$). However, significant main effect of age was observed for mother termination ($F = 16.3$, $P < .001$) and infant termination ($F = 20.0$, $P < .001$). Pairwise comparisons showed that mother termination increased from 2 to 6 months and decreased from 6 to 9 months. On the other hand, infant termination increased from 2 to 6 and from 6 to 9 months. Paired samples *t*-tests showed that in both groups, infants terminated interactions more often than mothers (Table 3).

3.3 | Types of interaction

As expected, Humor appeared from 6 months and Joint Attention appeared from 9 months. Thus, MEM was not calculated for Joint Attention. Results showed no significant interaction group × age effect for Independent Play ($F = 1.6$, $P = .197$), Interpersonal Interaction ($F = 0.2$, $P = .877$), and Humor ($F = 1.5$, $P = .220$). Moreover, significant main effect of age was not observed for either Interpersonal Interaction ($F = 1.0$, $P = .383$) or Humor ($F = 2.2$, $P = .154$), but it was observed for Independent Play ($F = 9.1$, $P < .001$). Pairwise comparisons showed an increase in Independent Play from 4 to 9 months. Also, significant main effect of group was observed for Interpersonal Interaction ($F = 4.5$, $P = .038$) and Joint Attention ($F = 5.1$, $P = .042$), but not for Independent Play ($F = 2.7$, $P = .108$) and Humor ($F = 1.5$, $P = .233$), with the ADHD group showing significantly shorter duration of Interpersonal Interaction and Joint Attention, compared to the control group.

3.4 | Predictive model

Attempting to conceptualize factors that predict the type of mother–infant interaction, a potential model was constructed according to the aforementioned idea that timing parameters may affect the content and the complexity of mother–infant interaction (Malloch & Trevarthen, 2009). This model consists of two submodels as follows: Submodel (A) examines factors that may affect synchronization at 2 months, that is, *protoconversations*. Even though one can imagine a plethora of such possible factors, in the present study the following time parameters were examined: duration of maternal behavior, duration of infant behavior, overlap, latency as well as mother and infant initiation. Sub-model (B) examines the effects of time parameters at 2 and 9 months as well as mother and infant initiation at 9 months on the duration of Joint Attention.

3.4.1 | Submodel (A)

The PLS analysis extracted one significant component. The *Q*š cum is 0.662, the *R*š*Y* cum is 0.749, and the *R*š*X* cum is 0.351. These regression results indicate that the

TABLE 4 Results of the partial least squares (PLS) regression: Standardized coefficients and Variance Importance in Projection (VIP)

Variable	Standardized coefficients	VIP
DUR_M2	0.421	1.716
DUR_I2	0.307	1.252
OVRLP2	0.228	0.850
INI_I2	0.198	0.734
INI_M2	0.071	0.290
LAT2	−0.042	0.170

TABLE 5 Results of the partial least squares (PLS) regression: Standardized coefficients and Variance Importance in Projection (VIP)

Variable	Standardized coefficients	VIP
DUR_M2	0.202	1.338
SYN2	0.192	1.270
DUR_M9	0.174	1.155
DUR_I2	0.158	1.047
DUR_I9	0.127	0.843
INI_M	0.122	0.789
INI_I	−0.118	0.784
SYN9	0.066	0.436

principal component generated by the PLS regression summarizes quite well the regression model. Table 4 presents standardized coefficients of the PLS regression and the VIP. The VIP of duration of maternal behavior and duration of infant behavior is more than 1, so these variables are significant factors influencing synchronization of the dyad at 2 months, although the effect of duration of maternal behavior is greater. The VIP value of overlap is less than 1 but more than 0.8, indicating that this variable is inferior in influencing the duration of synchronization than the other factors (Table 4).

3.4.2 | Submodel (B)

The PLS analysis extracted one significant component. The *Q*š cum is 0.586, the *R*š*Y* cum is 0.710, and the *R*š*X* cum is 0.495. These regression results indicate that the principal component generated by the PLS regression summarizes quite well the regression model. Table 5 presents standardized coefficients of the PLS regression and the VIP. The VIP of duration of maternal behavior at 2 and 9 months, synchronization at 2 months, and duration of infant behavior at 2 months is more than 1, so these variables are significant factors influencing synchronization of the dyad, although the effect of duration of maternal behavior is greater. The VIP value of duration of infant behavior at 9 months is less than 1 but more than 0.8, indicating that this variable is inferior in influencing the duration of Joint Attention than other factors.

4 | DISCUSSION

To our knowledge, this is the first, yet preliminary, naturalistic study that examines longitudinally the development of interaction between infants and their mothers with ADHD symptoms. Mothers were designated as ADHD and controls according to the ASRS and the DIVA. The dyads were video recorded during free play interactions at 2, 4, 6, and 9 months and microanalysis was carried out to assess aspects of timing, turn-taking, and type of interaction.

Results demonstrated that in both groups synchronization increased during the period of the study, whereas overlap decreased from 2 to 4 months reaching less than 300 ms. Because synchronization was significantly negatively correlated with overlap ($r = -.337$, $P = .008$), it seems that both groups improve their attunement, achieving a better organization for their interaction. This is particularly the case for the ADHD group, which exhibited longer overlap compared to the control group at 2 months. However, in accordance with the first hypothesis, it was shown that dyads in which mothers reported ADHD symptoms devoted approximately half time in synchronization compared to dyads in which mothers did not report ADHD symptoms. This difference was observed throughout the period of the study and increased further after 6 months. Shorter synchronization in ADHD dyads may be attributed mainly to duration of maternal behavior. Indeed, it was shown that although both mothers and infants in the ADHD group exhibited significantly shorter behavior duration than mothers and infants in the control group, primarily duration of maternal behavior predicted synchronization. In addition, it was shown that in the ADHD group duration of maternal behavior did not differ significantly from duration of infant behavior, whereas in the control group duration of maternal behavior was significantly longer compared to the duration of infant behavior. Thus, it seems that in the control group mothers provide a more extended framework for communicative interaction, whereas this framework is remarkably restricted in the ADHD group.

Regarding the type of interaction, mothers in the ADHD group dedicated significantly less time to person–person interactions compared to the control group during the period of the study. Person–person communication is manifested from birth and reaches its climax at 2 months with *protoconversations* (Trevarthen, 1998). In

protoconversations, mother's expressions with their fluctuating energy support infant's intentions in time and in relation to the shared vocal, tactile, and motoric events. On the other hand, the infant takes an active role by sharing the mother's chat and mirroring feelings with smiles and coos. The "intermodal fluency" of mutual "attunement" between mother and the 2-month - old infant reveals an intuitive enhancement of rhythm and emotion. This type of interpersonal interaction trains infant's self-awareness and consciousness of agency (Malloch & Trevarthen, 2009; Trevarthen, 1998).

Around 6 months, new developments are observed in infant self-awareness. At this age, infants tend to explore new ways of testing the limits of other person's interest and knowledge. This is accompanied by a strong sense of humor, by which infants express to others' emotional evaluations of what they do and know (Reddy, 2008). In this study, as expected, dyads in both groups exhibited humor from 6 months and did not differ in the duration devoted in teasing behaviors.

Nevertheless, group differences were observed in Joint Attention that appeared at 9 months, with these episodes lasting almost three times less in the ADHD group, compared to the control group. At this age, typically developing infants exhibit a new readiness to tune in with intentions, interests, and emotions of a partner, in order to achieve a common goal (Tomasello & Carpenter, 2007; Trevarthen & Hubley, 1978). This so called *Secondary Intersubjective Attunement* is manifested in a triangular subject–subject–object format in which objects of joint attention and emotional referencing are brought into play as occurrences of mutual attention within trusting relations of companionship (Bråten & Trevarthen, 2007; Trevarthen & Hubley 1978).

Findings of the present study show similarities as well as differences from other relevant studies. Specifically, Semple et al. (2011) demonstrated that lower sensitivity scores based on a lack of maternal behaviors requiring focused and sustained attention were related to infant negative affect. Similarly, in this study it was demonstrated that shorter duration of maternal behavior was a causal factor of shorter duration of interpersonal interactions. However, a more direct comparison of the present study with Semple et al.'s (2011) study is not possible because different aspects of behavior are examined.

Landau et al. (2009) found that 7-month-old infants at familial risk from father's side for ADHD did not differ from the control group in joint attention behaviors, for example, trying to give a block to parent while playing, pointing to a reachable block and looking at the parent, or holding and showing a block to the parent. These findings contrast the finding of the present study that the duration of joint attention episodes was significantly shorter in the ADHD group compared to the control group. However, it should be noted that in Landau et al.'s study infants were 2 months younger from the age that joint attention appears consistently. At 7 months, only sporadic signs of joint attention can be observed, and this is confirmed by the low frequencies of the behavior reported by the authors (Landau et al., 2009). Moreover, Landau et al. observed joint attention behaviors in a highly structured experimental condition and not in a naturalistic setting as in this study.

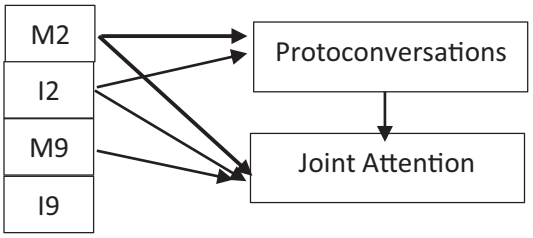

FIGURE 2 A potential model of the effect of timing parameters on the type of mother–infant interaction (bold arrows depict the strongest effect)

The present study attempted to further investigate factors that may affect the development of more complex forms of mother–infant interaction. Results demonstrated that *protoconversations*, which is the primary manifestation of innate motives for communication, seems to be mainly affected by duration of maternal behavior. In turn, *protoconversations* are predictive of more developed forms of intersubjective communication such as joint attention (Figure 2). Thus, it seems that infant's ability for more complex forms of cooperative communication is strongly influenced by earlier forms of communication, that is, *protoconversations*, which in turn are significantly predicted by duration of maternal behavior. In other words, shorter duration of *protoconversations* and joint attention episodes in ADHD dyads may be at least partly attributed to shorter duration of maternal behavior. Indeed, it seems that mothers with ADHD symptoms cannot maintain their behavior for enough time possibly due to the core symptoms of the disorder, that is, inattention, hyperactivity, and impulsivity. This maternal deficiency seems to affect temporal coordination between mothers and their infants and maybe the development of more complex forms of interaction.

Findings of the present study may be accounted for by the theoretical model of *Communicative Musicality* proposed by Malloch and Trevarthen (2009). Communicative musicality is defined as the expression of uniquely human innate motives for cultural learning. Communicative musicality consists of three elements, namely, pulse, quality, and narrative. Pulse refers to the timing of expressive behaviors, quality consists of the form of the expression, and narrative is the expression of innate motives for sharing emotion and experience with other persons and

for creating meaning in joint activity with others (Stern, 1993; Trevarthen, 1998). Intercoordination of human activities is regulated by Intrinsic Motive Pulse (IMP), which is generated by a brain network that involves the brain stem, the basal ganglia, and limbic structures (Trevarthen, 2016). A fundamental manifestation of communicative musicality is the intercoordinated communicative interactions between mothers and their infants, which are based on both partners' endowments for perceiving and producing timing patterns. In this way, partners are highly attuned and form a critical time framework for the development of complex forms of communication. Failed attunement, as in cases of postpartum depression, may have short-term as well as long-term effects on infant communicative and cognitive functioning (Malloch & Trevarthen, 2009). Murray and Cooper (1997) suggest that what is important to the child's functioning is not her exposure to depressive symptoms per se, but the impaired patterns of interaction occurring between mother and infant in the context of depression. In this case, disturbed patterns usually result from mother's impaired ability to maintain attunement with infant emotions and interests. In accordance with the above considerations, the present study demonstrated that mothers with ADHD symptoms exhibit relatively short behaviors that result in shorter synchronization with their infant. It seems that in cases the time framework devoted in mother–infant interaction during the first year is limited, the development of infant's ability for more complex forms of interaction, such as joint attention, is strongly affected.

A follow-up study of the present participants in preschool and school age assessing aspects of cognitive, language, and social development as well as academic functioning will shed further light to the effects of maternal ADHD symptoms on child development. Also, future research may directly compare interactions between infants and their mothers with ADHD with interactions between infants and their mothers with other disorders such as depression or anxiety. Of interest will also be to study gender differences in early interactions between infants and their mothers with ADHD symptoms.

Despite its potential contribution, the present study has several notable limitations. One is the restricted sample size that increases the risk of type II errors. Moreover, some behaviors were observed for a very short time in either group weakening thus any group comparison. Also, the results might not generalize to mother–daughter relationships. However, it provides useful data on the development of temporal characteristics and type of interactions between infants and their mothers with ADHD symptoms that can be utilized for early diagnosis, early intervention, and secondary prevention of accompanying problems of ADHD.

4.1 | Clinical implications

The present study may have important clinical implications for early diagnosis and intervention of ADHD as well as secondary prevention of accompanying problems that are manifested later, that is, academic failure, behavioral problems, poor social relationships, and low self-esteem (Maniadaki & Kakouros, 2017).

Early diagnosis is based on identification of early markers predicative of the development of ADHD. Some studies propose that developmental immaturity, increased activity level, emotional dysregulation, overresponsivity to emotional stimulation, and lower cognitive functioning may render some infants vulnerable to psychopathology (Campbell, Halperin, & Sonuga-Barke, 2014; Sonuga-Barke, Auerbach, Campbell, Daley, & Thompson, 2005). However, these behavioral markers are usually nonspecific; that is, they are indicative of risk for psychopathology, but cannot determine which type of pathology will develop in later childhood (Maniadaki & Kakouros, 2017). In fact, empirical data regarding precursors of ADHD in infancy are extremely limited. Nevertheless, studies conducted on infants at familial risk for ADHD reveal that behavioral markers of vulnerability to ADHD may be present even in the neonatal period. Such markers include poor motor maturity and autonomic stability, increased levels of motor activity, poor sustained attention, irritability, and negative emotionality (Auerbach et al., 2005; Green & Goldwyn, 2002; Karalunas et al., 2014; Shaw, Stringaris, Nigg, & Leibenluft, 2014). The present study may contribute to the identification of a behavioral pattern during infancy that is specifically related to ADHD, by revealing temporal characteristics as well as quality of play in mother–infant interactions.

Early diagnosis of ADHD constitutes a prerequisite for the implementation of early intervention programs that aim at secondary prevention. The efficacy of early intervention mainly lies in the fact that it takes place during the period of great brain plasticity that allows for generalized long-lasting modifications of the underlying neurophysiology (Sonuga-Barke & Halperin, 2010). Secondary prevention detects the emerging disorder at its earlier stages and attempts to inhibit its progress, slow its escalation in severity or persistence, modify its course, and reduce adverse outcomes through procedures that allow for the conversion of adverse brain development. Thus, early intervention that focuses on processes that have a causal relationship with ADHD may prevent the manifestation of secondary problems that emerge from the core symptoms of the disorder, that is, inattention, hyperactivity, and impulsivity. Moreover, efficacy of early intervention is enhanced because it occurs before the child has developed strong behavioral habits that lead to functional

impairment and before parents have established maladaptive attitudes that reduce their receptiveness and the efficacy of family-based interventions (Sonuga-Barke & Halperin, 2010).

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