

**Abstract****Background**

According to the *DSM-V* (APA, 2013), autism spectrum disorder (ASD) is a developmental disability characterized by social-communication deficits and repetitive-stereotyped behaviors. Social-communication deficits have a major effect on the peer interactions of cognitively able ( $IQ \geq 70$ ) children with ASD (CAASD) (Bauminger-Zviely, 2013). In addition, children with ASD evidence a high prevalence of motor difficulties (Bhat et al., 2011), which are manifested both in the child's individual (gross and fine) motor coordination (Bhat, 2021) and in the child's dyadic motor activities such as coordinated joint action (CJA) with a social partner (Fitzpatrick et al., 2017b). Individual motor functioning has been positively associated with social functioning in the general population (Peyre et al., 2019) and, in several recent studies, in individuals with ASD as well (e.g., Bhat, 2021). However, a number of studies did not find a significant correlation between individual motor and social functioning in ASD (e.g., Bishop-Fitzpatrick et al., 2017). Other research has linked various social abilities with higher dyadic cooperative motor skills and with better executive functioning capabilities (i.e., the high-order mental functions responsible for organizing and coordinating behavior for the purpose of performing actions related to complex tasks) for children with typical development (TD) and children with ASD (e.g., Cheng et al., 2020; Fitzpatrick et al., 2017b; Jiang et al., 2021). The rare available research examining individual motor skills, executive functions, and social abilities together within a single study (MacDonald et al., 2016) found positive correlations between the child's motor skills and social abilities while controlling for executive functions in children with TD; however, as far as I know, researchers have not yet investigated these links for children with ASD.

**Research Objectives**

The main objective of this study was to explore individual and dyadic (CJA) motor functioning as well as executive functioning for their contribution to children's and adolescents' general social functioning and specifically to their ability to interact with peers. To examine developmental trajectories in participants with CAASD versus participants with TD, these measures were examined for group differences (TD / CAASD) and for age differences (early childhood / preadolescence / adolescence). Study results were expected to shed light on cognitive-motor mechanisms' contribution to participants' general social functioning and specific ability to engage in peer interactions. Outcomes were also expected to have implications for novel intervention design integrating motor and executive functioning to facilitate peer interaction and social functioning in CAASD.

## Hypotheses

**First**, children and adolescents with CAASD were hypothesized to show lower social measures (i.e., lower social functioning in general and lower peer interaction ability in particular) compared to children and adolescents with TD. The social measures were also hypothesized to improve with age for the TD group, but a hypothesis was not formulated for age in the CAASD group due to mixed results in previous findings.

**Second**, for the TD group, social measures (general functioning and peer interaction) were hypothesized to positively correlate with motor skills (individual and dyadic) and with executive functions. Based on prior studies, the same hypothesis was formulated for the CAASD group. The question regarding the correlation between the individual motor measures and the social measures remains open due to inconclusive preceding findings.

**Third**, milder autistic symptoms among CAASD participants were hypothesized to correlate with more intact social functioning and peer interaction capabilities. No hypothesis was formulated for the correlation between cognitive abilities (IQ) and the social measures in either group due to the paucity of previous research.

**Fourth**, motor skills (individual and dyadic) as well as executive functions were hypothesized to significantly explain the variance in participants' social measures (general social functioning and peer interaction ability).

## Method

**Participants.** This study included 148 children and adolescents in two study groups: 64 with TD (including 16 girls) and 84 with CAASD (including 14 girls). Each study group included three age subgroups: early childhood (71 – 102 months), pre-adolescence (103 – 144 months), and adolescents (146 – 203 months). The participants in each study group (TD / CAASD) were divided into age, sex, and IQ matched pairs.

**Background measures.** Participants' prior ASD clinical diagnosis in the CAASD group was confirmed using the Autism Diagnosis Observation Schedule (ADOS-2<sup>nd</sup>; Lord et al., 2012). All participants' cognitive abilities were measured using the WISC-IV-HEB (Wechsler, 2010). Only participants with IQ  $\geq$  70 were included in the study.

### Research measures.

- *Specific peer interaction ability:* Direct observation of each participant during a 10-minute dyadic interaction while playing a shared construction game (Marble Works), coded for each participant's social behavior during interaction (using the Friendship Observation Scale; FOS) and for the quality of the dyadic interaction (using the Dyadic Relationships Q-Set; DRQ) (e.g., at Bauminger et al., 2008).
- *General social functioning:* Parent-rated Social Responsiveness Scale (SRS), completed by mothers (Constantino & Gruber, 2005).

- *Individual motor skills:* Individual Motor Observation Scale (IMOS), assessing gross motor, fine motor, and overall scores (Bauminger-Zviely, Estrugo, & Shafir, 2017).
- *Dyadic motor skills:* Direct observation of each participant's CJA (Coordinate Joint Action) performance in four dyadic tasks (two mirroring tasks, e.g., imitating movement, and two completion tasks, e.g., imaginary football play), coded for two coordinated joint movement scores (mirroring and completion) (Bauminger-Zviely, Bar-Yehuda, & Shafir, 2017).
- *Executive functions:* Parent-rated Behavior Rating Inventory of Executive Function (BRIEF), completed by mothers (Gioia et al., 2015).

## Results and Conclusions

Consistent with the first research hypothesis, the children and adolescents with TD exhibited better peer interaction abilities (on the FOS and DRQ) and were rated by parents as functioning socially within the normative range (SRS), whereas their counterparts with CAASD showed more social dysfunction on all these measures. Surprisingly, participants with TD presented only moderate improvement with age on some social dimensions (i.e., on the FOS: goal-directed behavior, caring and empathy, coordinated play, and social engagement; on the DRQ: coordinated play), but improvement with age was noted across all measured social dimensions for the CAASD group. Perhaps improvement trends were less noticeable in participants with TD because they already showed mature social functioning at young ages, while participants with CAASD needed extra time to develop these abilities. Support for this explanation was found in the lower functioning shown by adolescents with CAASD as compared to young children with TD for several social dimensions (i.e., degree of shared fun and level of social engagement during interaction).

Regarding the second hypothesis, correlation analyses demonstrated that better motor functioning (individual and dyadic) and better executive functions were linked with a significantly higher quality of peer interaction (DRQ) for the CAASD group. For the TD group, motor skills (individual and dyadic) and executive functions showed no significant correlations with the social measures. Presumably the non-significant link between cognitive-motor functioning and social functioning for the TD group may be explained by this group's lower variance in the social functioning measures (possible due to early maturation of those skills), which could have limited the ability to reliably tap those correlations for this group.

One surprising finding was the link between better social functioning and higher executive dysfunction in the TD group. This finding can be explained by looking more deeply at the meaning of the BRIEFs scores obtained for each group. Participants in the TD group scored, on average, in the 38<sup>th</sup> percentile (considered the normative range on the BRIEF), whereas the CAASD group's average score was in the 91<sup>st</sup> percentile,

underscoring high executive dysfunction. Despite this unexpected finding, participants in the TD group nevertheless scored within the normative range on the BRIEF regardless of whether their peer interaction was coded with a higher or lower quality on the DRQ.

In line with the third hypothesis, participants with higher ASD symptom severity exhibited lower peer interaction abilities. Also, almost no significant correlations emerged between IQ and the social measures for either study group, probably due to the fact that all the participants in this study had a normal IQ range. Another possible explanation is that the peer interaction task (Marble Works) had lower cognitive demands and therefore did not distinguish between participants with high and low cognitive ability.

Finally, executive functions (BRIEF) and individual (IMOS) and dyadic (CJA) motor functioning were examined for their contributions to explanations of participants' variance in this study's social measures (FOS, DRQ, SRS). Findings indicated that higher executive functions contributed to those peer interaction dimensions that focused on the participant's relations to the partner (e.g., higher caring and empathy). In addition, higher individual and dyadic motor skills contributed to those dimensions that focused on the participant's activity level within the peer interaction (e.g., higher goal-related behavior). Thus, the combination of executive functions and motor capabilities can explain the variance found in both better quality of interaction with a social partner and higher social activity level within the interaction.

Moreover, for the sample as a whole, the three-way interaction between individual motor skills, dyadic CJA, and executive functions also contributed to the explanation of the various social capabilities. For example, better dyadic motor skills contributed to several social measures (participants' higher degree of caring and empathy, goal-directed behavior, and the quality of dyadic interaction) when the participants' individual motor skills and executive functions were more impaired. This finding may reflect a compensatory mechanism. Prior literature has indicated that peer interaction is better when executive functions and individual motor skills are less impaired. However, when those capabilities are impaired, peer interaction capabilities can still be expected for participants with more intact dyadic motor skills.

These findings suggest the need for interventions to address a novel combination of individual motor skills, dyadic motor skills, and executive functions to promote peer interaction in both participants with CAASD and TD. Thus, future research should examine the effectiveness of intervention programs' inclusion of cognitive-motor mechanisms (individual and dyadic motor skills and executive functioning skills) to advance peer interactions in children with and without CAASD. Such integrative

models of social intervention may help reduce the loneliness and social isolation that often characterizes children and adolescents on the autism spectrum.