Social Approach in Autism: Modeling Objective Measurements of Child Movement in a Naturalistic Environment

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Abstract

Background.

Atypicalities in social approach are thought to be characteristic of children with autism spectrum disorder (ASD), but few studies have quantified the social movement of children with ASD using objective measures. The purpose of this paper is to introduce a new method—computational modeling of radio frequency identification (RFID) child tracking—for studying children with ASD in a naturalistic setting. We present the use of RFID measurements to investigate the velocity and social approach of children with ASD and typically developing (TD) children interacting together in preschool inclusion classrooms during repeated multi-hour observations.

Methods.

Observations of 14 preschoolers with ASD and 16 TD preschoolers in two inclusion classrooms on a total of 10 days yielded approximately 10 hours of data per child. Objective measurements of position and orientation were collected using four corner-mounted Ubisense ultra-wide sensors, which tracked a right and left tag worn by each child (in a vest) and teacher in the classroom. We calculate angular velocity, velocity, and social approach, and compare ASD and TD children on these parameters using multilevel statistical models.

Results.

In this initial exploration of the ASD phenotype *in situ,* children with ASD did not differ from TD children in angular velocity or velocity of movement in the classroom. Rather, pairs of TD children moved toward and away from each other at higher velocities than both pairs of children with ASD and pairs in which one child had ASD and the other child was TD. Children with ASD, however, moved toward and away from teachers at higher velocities than TD children.

Limitations.

Illustrative data from repeated observations of 30 children in two classrooms are reported. Results are preliminary.

Conclusions.

Multi-hour, objective measurements in a preschool inclusion classroom indicated that children with ASD did not move through space or turn at higher velocities than other children. Instead, ASD differences were evident in social approach. Children with ASD were slower in approaching peers but quicker in approaching teachers than were TD children. The results suggest the potential of modeling RFID measurements to produce a quantitative understanding of the ASD phenotype in naturalistic social contexts.

Keywords: Autism spectrum disorder, social approach/avoidance, velocity, objective, automated, inclusion, classroom

Background.

Movement supports the initiation, maintenance, and termination of social interactions, and allows for physical exploration of the surrounding environment [1]. Children with autism spectrum disorder (ASD), a developmental disorder characterized by atypical social communication and repetitive behaviors, exhibit a range of movement abnormalities [2]. Impaired movement has implications for social development, as children with motor difficulties were more likely to withdraw from social interactions [3]. One possibility is that impaired movement in the development of children with ASD may limit interactions, increasing the severity of core ASD symptoms [4]. Here, we utilize location-tracking devices in preschool classrooms to illustrate how researchers can use objective measurements to gain insight into movement patterns in general, and social movement in particular, in children with ASD.

Despite debate about the role of gross movement difficulties in children with ASD, there is little research exploring movement differences between children with ASD and their typically developing (TD) peers in naturalistic settings. In preschool classrooms, children locomote both to physically explore and to socially engage with peers and teachers. Location tracking in inclusion classrooms, in which teachers educate children with ASD alongside TD children, is ideal for investigating movement and social interaction differences in children with ASD and their TD peers [5].

Researchers have examined both the Euclidean velocity (speed of movement) and the angular velocity (speed of spinning and circling) of children with ASD [6–8]. Evidence for Euclidean velocity differences is scant between children with and without ASD, with six of nine recently reviewed studies indicating no differences [9]. With respect to angular velocity, Cohen et al. [10] and Bracha et al. [11] found that children with ASD exhibited a counterclockwise turning bias, although Yang et al. [12] found that children with ASD exhibited faster rotation in both a clockwise and a counterclockwise direction than TD children. Here, we demonstrate how objective measurements can be used to compare both the Euclidean and angular velocity of children with ASD and their TD peers in naturalistic contexts.

Atypicalities in social approach characterize social communication deficits in children with ASD and help define the severity of the disorder [13,14]. Previous research has examined social approach using manual (human) coding of movement toward or away from peers during social interaction [15]. Manual coding of the frequency of interactions in a preschool inclusion classroom has not indicated differences in latency to engage in interaction in children with ASD and their TD peers [16]. However, even trained human observers cannot simultaneously track the movement of each child in a classroom.

New technologies have potential for continuously measuring children's movement and social approach toward peers and teachers in dynamic classroom environments. For example, tracking multiple objects via video (such as children and teachers) is a well-studied computer vision task. Current approaches include the adoption of deep neural networks to improve the precision and accuracy of computer vision tracking [17]. Although computer vision tracking has yielded promising results in clinic situations [10], the precision of tracking based on RGB (red, green, blue) videos in 3D space is fundamentally limited by the loss of depth information during data acquisition. An alternate strategy is to supplement RGB video with D (depth) information (RGB-D) to improve performance [18], which has illuminated the role of withdrawal behaviors in ASD assessment [19]. Nevertheless, even RGB-D is subject to occlusion, in which the object of interest is blocked by intervening objects. RGB-D may be prone to frequent data loss in complex environments involving multiple persons, such as classrooms.

An alternate objective approach to exploring movement (and orientation) involves the use of radio frequency identification (RFID) to track the location of tags worn by multiple participants in complex environments [20–22]. RFID was recently validated for tracking children's movement in the preschool classroom [20] using a commercially available (Ubisense) system. Likewise, this system has also been used to conduct location-tracking in a general education kindergarten classroom [23]. In the current study, individuals (children and teachers) wore two RFID tags, which yielded information on orientation and location, to compare the movement of children with ASD and their peers in a naturalistic context, the preschool classroom. In the following section, we illustrate how researchers can examine children's individual movement patterns (i.e., angular and Euclidean velocity) and then present measures of social movement (i.e., children approaching and being approached by peers and teachers).

Methods.

Participants

Consent was obtained for 30 of 31 children. The 30 preschoolers were observed in two inclusion preschool classrooms (*M*=46.47 months, *SD*=8.29 months), each of which contained 15 children. A total of ten observation sessions (five in each classroom) yielded a mean of 4.20 (*SD*=1.32) observations per child. Observations were conducted over the preschool day, which was divided into a morning and afternoon half-day session. In each classroom, children with ASD attended either the morning or afternoon half-day session; TD children (with one exception) attended both sessions. Overall, approximately ten hours (M=606.4 minutes, SD=289.7) of data were collected per child.[1]

Classrooms employed the Learning Experiences and Alternative Program (LEAP) curriculum, which uses evidence-based practices designed to promote social interactions between children with ASD and their TD peers [24]. ASD status was established by the child's primary category of eligibility from his or her Individualized Educational Program (IEP). There were 14 children with ASD (2 female) and 16 TD children (12 female). Children were both Hispanic (16) and non-Hispanic (11), and ethnicity information was not available for 3. Children were white (24), black or multiracial (2), and information on race was not available for 4. There were 6 teachers, all female, 3 in each classroom.

Data Collection

RFID allowed for automated real-time assessment of children's location and orientation. These measurements were collected using the Ubisense Tag Module Research Dimension4 with Research Upgrade (see **Figure 1**)**.** The Ubisense system tracks children's positions 2-4 times per second (4 Hz) to an accuracy of 15cm in three-dimensional space in the classroom (8.86 x 8.97 m; Irvin et al., 2018). Four radio cell sensors (linked by a network cable) in the corners of the classrooms provided data to a dedicated laptop running Ubisense Location Recorder software. Using RFID, sensors tracked active tags worn by children (and teachers). Tags were located in space by means of triangulation (angle of arrival,

[1] One child (with ASD) refused to wear a vest on two of the four observations they attended.

AoA) and time differences in arrival (TDoA). Each individual wore two tags (left and right) to provide orientation information orientation—the direction being faced (see **Eq. 1**)—in pockets sewn into a specially-designed vest (a fanny pack for teachers). The midpoint of the tags' XY coordinates indexed an individual's location. Location can be used to visualize individual movement throughout the school day (see **Figure 2**).

Insert **Figure 1** and **2** here

Measures

Tag location data were interpolated for each consecutive tenth of a second. Velocities were computed as differences in location between consecutive tenths of a second and smoothed using a moving average of order 10.

Angular Velocity. Angular velocity (turning over time) was computed as the difference in the orientation angle of each child's right and left tags with respect to an imaginary line bisecting the classroom. The equation may be written:

$$Angular\ velocity[t] = \theta[t] - \theta[t-1] \quad \textbf{Eq. 1}$$

where $\theta[t] = atan2((x_R[t] - x_L[t]), (y_L[t] - y_R[t]))$ and $x_R[t], y_R[t], x_L[t],\ y_L[t]$, and θ[t] are the x- and y- coordinates of right tag, x- and y- coordinates of left tag, and orientation at time *t*. Positive and negative values of angular velocity indicate counterclockwise and clockwise rotation, respectively.

Euclidean Velocity. Each child's position was calculated as the midpoint of their left and right tags. Euclidean velocity (displacement over time) was computed as the difference in position of each child as follows:

$$Euclidean\ velocity[t] = \sqrt{(x[t] - x[t-1])^2 + (y[t] - y[t-1])^2} \quad \textbf{Eq. 2}$$

where $x[t] = \frac{1}{2}(x_R[t] + x_L[t])$ and $y[t] = \frac{1}{2}(y_R[t] + y_L[t])$.

Social Approach Velocity. To determine social approach velocity, we first calculated the distance each child or teacher moved toward or away from the initial position of their partner (child or teacher). Positive and negative values indicate moving toward and away from a partner, respectively.

We begin by defining the distance from child A to partner B at t:

$$Distance_{A\rightarrow B}\,[t-1] = \sqrt{(x_A[t-1]-x_B[t-1])^2+(y_A[t-1]-y_B[t-1])^2} \quad \textbf{Eq. 3A}$$

And define subsequent distance as the distance between A's location at t and B's location at $t-1$:

$$Subsequent\ Distance_{A\rightarrow B}\,[t] = \sqrt{(x_A[t]-x_B[t-1])^2+(y_A[t]-y_B[t-1])^2} \quad \textbf{Eq. 3B}$$

Thus the difference between these distances reflects A's movement toward B's previous location:

$$Approach_{A\rightarrow B}\,[t] = Distance_{A\rightarrow B}\,[t-1] - Subsequent\ Distance_{A\rightarrow B}\,[t] \quad \textbf{Eq. 3C}$$

The logic here is to capture A's movement toward B (while temporarily disregarding any movement of B with respect to A). The approach parameter $Approach_{A\rightarrow B}$ was weighted by A's orientation to B and the orientation of A's movement toward B (more direct orientation was weighted more heavily), and A's distance from B (movement from a closer position was weighted more heavily). Specifically, we utilized $\theta_o[t-1]$—the orientation of the approaching child to the child being approached, $\theta_m[t]$—the angle of movement of the approach relative to the child being approached, and $Distance_{A\rightarrow B}$, initial distance between the pair, to weight $Approach_{A\rightarrow B}$ as follows:

$$Social\ Approach_{Weighted}[t] = \frac{Approach_{A\rightarrow B}[t]\cdot cos^2(\theta_o[t-1])\cdot cos^2(\theta_m[t])}{Distance_{A\rightarrow B}[t-1]} \quad \textbf{Eq. 4}$$

Recall that social approach can take positive (approaching) and negative (withdrawing) values. In **Eq 4**, orientation angle is used to weight approaches. Higher weights are assigned when A is directly facing B (oriented at 0º) or when A is facing directly away from B (oriented at 180º). These angles characterize A's instantaneous orientation with respect to B. We are also concerned with the angle of A's movement with respect to B, which follows an identical logic. That is, direct movement toward or away from B is weighted more heavily than movement perpendicular to B. Finally, approaches from closer locations are weighted more heavily, and approaches from more distant locations are weighted less heavily.

Correlating Social Approach. Each child approached and was approached by every other child and teacher. The velocity of A's approach of B and B's approach of A may be associated. To capture possible associations in reciprocal approaches, correlations of social approach over time were calculated each minute. These correlations index the degree of concordance of social approach between each child and partner. Positive correlations indicate that both interacting partners are moving toward or away from each other. Negative correlations indicate that one interacting partner is moving toward and the other is moving away, a following pattern.

Mixed effects models

Observations were nested in children, and a child-level random intercept term was incorporated in all relevant models. Mixed effects (multilevel) modeling was conducted R [25]. Mixed effects regression models were compared using the lmer function in the "lme4" package, and effect sizes were calculated using the lme.dscore function in "EMATools." Models employed restricted maximum likelihood (REML) for parameterization and maximum likelihood estimation for model comparison [26]. Predictors were added sequentially, and their significance was estimated by comparing models with and without the predictor of interest, where differences in model deviance [-2*(Log Likelihood)] were distributed as chi-square. Between-subjects effects were parameterized as an ASD intercept with TD contrasts. Differences in half-day sessions differences were parameterized as an afternoon (PM) contrast with a morning (AM) intercept.[2] The *B*s, standard estimates (*SE*), *t*s, Cohen's *d*s and 95% confidence intervals (CI) from final models are presented.

Results.

Velocities.

Mixed effects models of velocity incorporated a child-level intercept reflecting the ASD mean and an effect contrasting TD velocity with this intercept. TD children and children with ASD did not differ in the angular velocity of their counterclockwise, or clockwise turning (see **Table 1**; counterclockwise p=.82; clockwise p=.75). Likewise, TD children and children with ASD did not differ in their Euclidean velocity (see **Table 1**, p=.46). Angular velocity in both counterclockwise and

[2]Models allowing for the interaction of the AM/PM contrast with all parameters in a model showed the same pattern of significant results presented here (see Supplemental Tables).

clockwise directions was higher in the AM than PM (*p*s=.04), and there was no AM/PM difference in Euclidean velocity (*p*=0.70).

Peer Social Approach

Social approach velocity took positive values when children were approaching peers and negative values when children were moving away from peers. In modeling positive values, fixed effects for each model included the effect of the afternoon (with respect to morning) session, an approaching child term (TD with respect to ASD), a term for the child being approached (TD with respect to ASD), and a term for the interaction of the two child-level contrasts. Random effects for each model included a child-level intercept for both the child approaching and the child being approached. The modeling of negative values—the velocity at which children moved away from one another—used identical terms. . Colloquially, we asked how quickly child A approached (or moved away from) child B for all pairs of children where a TD versus ASD contrast was estimated for A and for B.

Children with ASD and TD children did not differ in the velocity with which they approached other children (see **Table 2**, *p*=.11). However, TD children were approached by other children at lower velocities than children with ASD were approached (*p*=.02). Additionally, a significant interaction effect indicated that TD children approached other TD children at higher velocities than other pairs of children approached one another (see **Figure 3**, *p*<.01). Results for the negative value model were similar to that of positive values (see **Table 2**). There was not a significant difference in the velocities with which TD children and children with ASD moved away from each other (*p*=.13). However, children moved away from children with ASD at higher velocities than they moved away from TD children (*p*=.02). In addition, a significant interaction effect indicated that TD children moved away from other TD children at higher velocities than other pairs of children (*p*<.01). In both analyses the magnitude of *B* for the interaction effect was more than three times larger than either of the main effects (see **Figure 3**). Finally, approach and withdrawal velocities were higher in the afternoon than the morning (*p*<.01).

Insert **Figure 3** here

Correlations of Peer Social Approach

Having calculated social approach velocities for each pair of children, we asked whether pairs of children tended to move toward and away from each other at similar velocities. Specifically, we correlated the velocity of a child's approach to a partner and the partner's approach to that child at one minute intervals. These correlations changed rapidly over time (see **Figure 4**). Positive correlations occur when both the child and partner moved toward or away from one another over a one minute epoch. Negative correlations occur when the child moves toward the partner and the partner moves away from that child (or vice-versa). We analyzed positive and negative correlations separately. Correlations were normalized via Fisher's r-to-z transformation prior to mixed effect modeling.

Insert **Figure 4** here

Separate mixed effect models predicted positive and negative z-transformed correlations. Analyses included all pairs of children in the class. The intercept, which was allowed to vary randomly, references the mean of ASD-ASD pairs. The TD-ASD and TD-TD terms reference mean differences in the correlations of those pairs from the mean correlation of the ASD-ASD pairs. For the positive correlations, neither the TD-ASD (p=.87) nor the TD-TD (p=.78) term was significant, indicating that pairs of children did not evidence differential coordination in the velocity with which they approached one another (see **Table 3**). For the negative correlations, both the TD-ASD (p<0.01) and the TD-TD pairs (p=0.04) exhibited less negative correlations than ASD-ASD pairs (see **Figure 5**). While the effect sizes for the contrasts were moderate, the magnitude of the effects was extremely small. When withdrawing from one another (but not when approaching one another), children matched one another's velocities more strongly in the afternoon than the morning (p<.01).

Insert **Figure 5** here

Teacher Social Approach

We created mixed effect models predicting the positive and negative social approach velocity of children toward teachers, as well as the positive and negative velocities of teachers toward children. For children approaching teachers, models contained an ASD-referenced intercept, a TD contrast, an effect for PM (versus AM) sessions, and child-level random intercept variance. Children with ASD moved toward teachers at higher velocities than their TD peers (*p*=.02). Likewise, they moved away from their teachers at higher velocities than their TD peers (see **Table 4** and **Figure 6A**, *p*<.01). For teachers approaching children, models contained an ASD-referenced intercept, a TD contrast, an effect for PM (versus AM) sessions, and child-level random intercept variance. Teachers moved toward and away from children more quickly in the morning than afternoon sessions (*p*<.01). Teachers moved toward and away from children with ASD at higher velocities than they moved toward and away from TD children (see **Table 4** and **Figure 6B**, positive *p*=.01; negative *p*=.03). In sum, children with ASD and their teachers moved toward and away from each other more quickly than did TD children and teachers.

Insert **Figure 6** here

Correlations of Teacher Social Approach

Having examined how children approached teachers and teachers approached children, we asked whether their approach velocities were correlated. That is, we calculated correlations of child-teacher approach in a fashion that mirrored our calculation of peer approaches. Next, mixed effect models were used to analyze the positive and negative correlations of children and teachers. Terms including an intercept referencing children with ASD and teacher correlations, a TD contrast (TD child and teacher correlation), and a pair-level random variance term.

Positive correlations refer to social approaches where both members of the pair moved toward or away from one another simultaneously. Positive correlations with teachers did not differ significantly between children with ASD and TD children (see **Table 5**, *p*=.72). Negative correlations refer to social approaches in which one member of the pair moved toward and the other moved away. Children with ASD and teachers exhibited more negative correlations than TD children and teachers (*p*<.01). (see **Table 5 & Figure 7)**.

Insert **Figure 7** here

Discussion

The characterization of behavior in research on children with ASD is dominated by human observation, which is both an invaluable source of insight and inherently subjective. Human measurement limits the possibility of collecting large-scale datasets that characterize the behavior of children with ASD in naturalistic settings. By contrast, advantages of objective measurement approaches include levels of spatial and temporal precision that are beyond the scope of human observation, as well as increases in measurement efficiency that allow for analyses of big behavioral data [27,28]. Finally, objective approaches measurement allows for the dissemination of replicable measurement strategies such as those detailed in this report. RFID technology offers a strategy for expanding objective measurement beyond the clinic into more complex, multi-person environments.

Utilizing multiple RFID sensors (4 in the current study) minimizes occlusion and provides continuous tracking of individual tags worn by children and adults in complex naturalistic environments such as the preschool classroom. Messinger et al. [23], for example, used Ubisense measurements to document well-known gender segregation effects in social contact in a kindergarten classroom. Likewise, Altman, et al. [29] validated RFID-based motion tracking combined with vocalization detection with respect to teacher and peer reports of friendship in an inclusion classroom, for children with hearing loss.

In the current pilot study, objective measurements of children in their preschool classrooms over multiple days did not suggest differences in the angular velocity (rotation speed) or Euclidean velocity (overall speed) of children with ASD and their TD peers. Previous research indicated differences as to whether children with ASD turn more rapidly in a counterclockwise direction [10,11] or in both directions [12] than TD children. The null findings emerging from extended naturalistic data suggest that previously documented higher levels of angular velocity in children with ASD may be associated with the stress of diagnostic clinic visits. With respect to overall speed or Euclidean velocity, there are suggestions that children with ASD move more slowly than other children [8], but a preponderance of evidence indicates no differences in velocity [6,7,9]. Thus, the current results suggest that differences in linear velocity are not a characteristic of children with ASD.

Despite its centrality to our understanding of ASD, the limited literature on social approach has focused on how children with ASD approach their parents and clinicians (but see [16]). Specifically, color tracking of video suggested that children with ASD exhibited a greater latency to approach parents than children without ASD [10] while a depth-sensor approach indicated that the proportion of the free play segment during which a child moved away from the clinician administering the ADOS was positively associated with ADOS social affect impairment scores [19]. In the current study, children with ASD moved both toward and away from adult teachers at *higher* velocities than TD children, which may suggest an affinity of children with ASD for their teachers. Likewise, teachers moved toward and from children with ASD at higher velocities than they moved toward and away from TD children. Analysis of the degree of negative correlations between partners indicated that children with ASD engaged in slightly stronger pursuit or following patterns (negative correlations) with teachers than did TD children with teachers, which may suggest that higher levels of behavioral control than is present in the interaction of teachers and TD children.

With respect to peer approach, we found that pairs of TD children moved toward and away from each other at higher velocities than pairs of children in which one or both partners had ASD. This finding suggests greater fluidity of peer-directed, movement-based interaction among TD children than among children with ASD. It is noteworthy, however, that pairs of children with ASD were not slower in their movements toward and away from each other than ASD-TD pairs [30]. Although Jahr et al.'s [16] manual observations of preschool inclusion classrooms indicated that children with ASD engaged in fewer initiations leading to social interaction with peers, they did not differentiate approaches to TD children and children with ASD. Asking who is being approached may index differential engagement with children with ASD. In fact, correlations of paired approaches in the negative domain indicated that dyads composed of children with ASD (ASD-ASD) engaged in slightly more pronounced following patterns than dyads containing a TD child (TD-ASD and TD-TD). The results, then, suggest that it is imperative to distinguish who is approaching whom when investigating interactions among groups of children with and without ASD.

Overall, the current results suggest an intriguing parallel. TD children approached one another more quickly than other groups of children. By contrast, children with ASD approached (and were approached by) their teachers more quickly than TD children. This pattern may suggest that children with ASD engage in more fluid teacher-directed movement-based interaction while TD children engage in more fluid interactions with peers.

The purpose of this report is to demonstrate the utility of RFID tracking for understanding social movement in children with ASD. We focused on two inclusive classrooms (utilizing the LEAP curriculum) where children with ASD are educated alongside their TD peers. RFID can be applied to other types of inclusive classrooms as well as classrooms containing only children with ASD, or children with ASD and other types of developmental disabilities. More generally, RFID technology can be extended to the study of multiple children in complex social environments such as playgrounds, parks, lunchrooms, and public clinics.

While the initial costs of RFID equipment are relatively high ($13,000 USD in the current case), the long range benefits provided by a system capable of repeated observations in multiple venues contribute to the efficiency of this objective approach as compared to manual observations. Finally, parental consent to the current research was high (>95%), and the vests containing Ubisense tags were well-tolerated by children with ASD (>98%) in the current study. High levels of consent and vest-wearing, along with economies of scale, suggest the potential of RFID-based measurement as part of the ASD-researchers toolbox.

Limitations and Future Directions

The current study includes a small sample (n=30) of children observed on repeated occasions (M = 4.2) in two classrooms. Despite the stability provided by lengthy repeated longitudinal observations, the small sample size should condition interpretation of results. Observing inclusion classrooms allowed for measurement of children with ASD and TD peers simultaneously in the same environment. However, in the specific classrooms observed, children with ASD were observed either during the morning or afternoon, while TD children remained in the classroom for the entire day. A series of supplemental models (see Supplemental Materials) indicate that ASD contrasts are unchanged when controlling for the AM/PM contrast and its interaction with ASD contrasts. Nevertheless, ASD contrasts must be interpreted in light of the likelihood that TD children were likely more familiar with one another than children with ASD. Future research should examine these contrasts in a variety of classrooms and other contexts not affected by differential contact. Likewise, the current classroom-based context used children's educational records to establish their disability status. Future research might explore associations between children's (social) movement and continuous indices of autism severity.

Conclusions

The current RFID-based approach is the first objective characterization of social approach among children (with or without ASD) in their everyday environments and sets the stage for future research in this domain. ASD is defined in part by persistent deficits in social interaction. In practice, however, observations of children with ASD typically occur in clinical and laboratory contexts and are of relatively brief duration. Classrooms are dynamic environments characterized by continuous movement. To complement manual observations conducted in classrooms, we harnessed a relatively new and economical commercially available technology (RFID) to conduct repeated observations of children with ASD and their TD peers. These observations yielded over 10 hours of data for almost every child in a naturalistic context including peers and teachers. Children's individual movement velocity, and the velocity which they approached and withdrew from peers and teachers was calculated using a series of equations which are instantiated in freely available code (R and C#). A computational approach to understanding social movement will allowed for the quantifications of velocity differences in social approach (who approaches whom) in children with and without ASD and their teachers. Results suggest new areas of research in understanding how children with ASD interact with peers and teachers. The research is part of a broader movement that harnesses new digital technologies to better understand children with disabilities in order to positively impact their social functioning.

Declarations

Ethics approval and consent to participate

Recruitment and procedures were approved by the University of Miami's Social and Behavioral Sciences Institutional Review Board (reference number: 20160509).

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available on the Open Science Framework: https://osf.io/kftvw/?view_only=4ccdc7a937684ce7b32ac4848a5e0d98

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

DSM designed the study. RMF and LV collected the data. DSM, CS, YT, and CB designed the measures. LV, MS, YT, and CB created the data pipeline. CB and LKP analyzed the data. CB conducted supplemental analyses. CB and DSM wrote the manuscript. LKP, RMF, and YT edited the manuscript.

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Figures

Figure 1

Vest and RFID trackers. Note. Vest with pockets for Ubisense tags (1” x 1” x .36”).

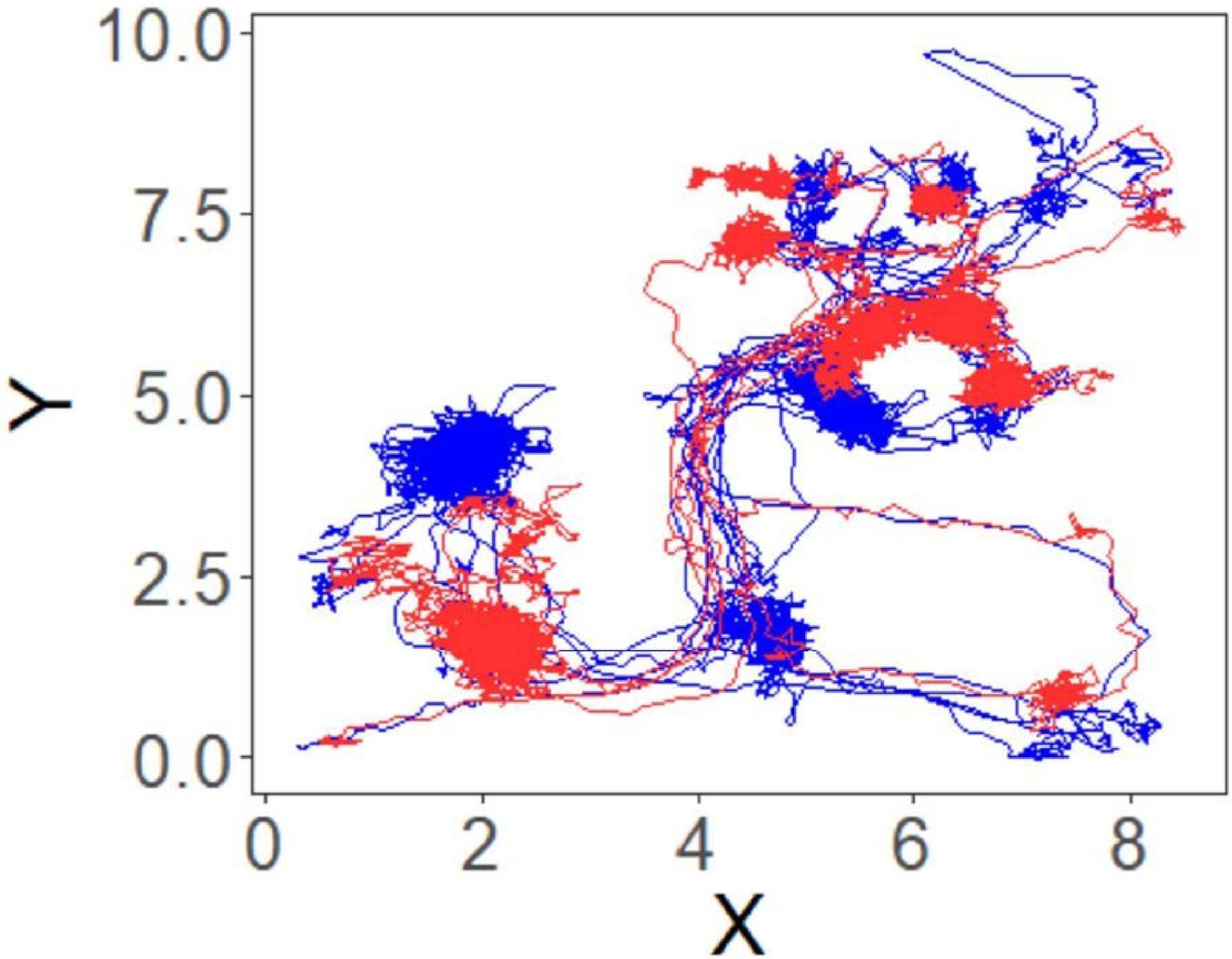


Figure 2

Location Trajectory over School Day. Note. Trajectory of two children (blue=ASD, red=TD) over the course of one half-day session in a preschool classroom as measured by RFID . X and Y refer to the width and length of the classroom in meters.

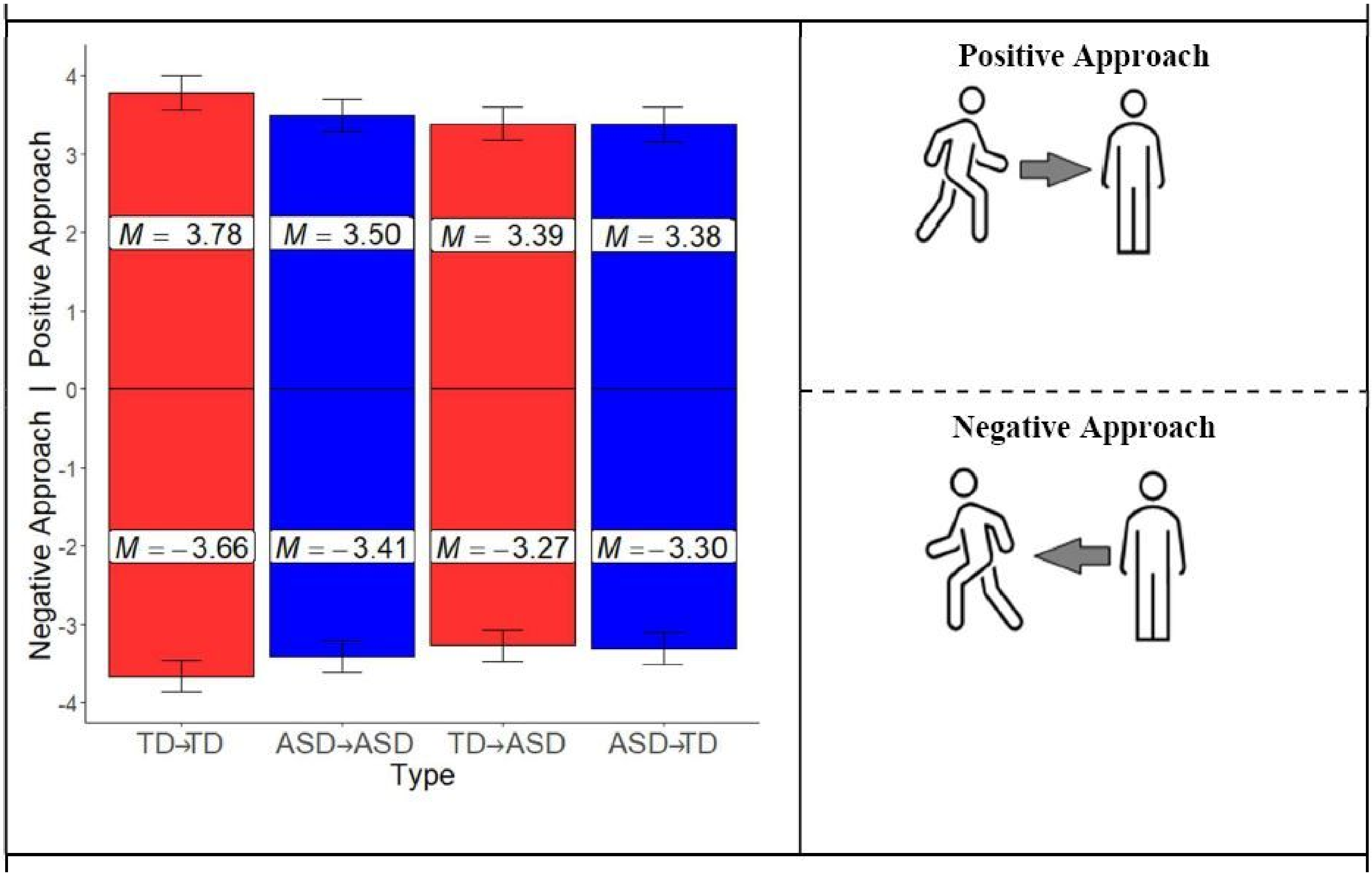


Figure 3

Peer Social Approach. Note. Social approach is measured in cm/s. Positive approach indicates a child moving toward a peer. Negative approach indicates a child moving away from a peer. Arrows are directional, such that TD→ASD indicates a TD child moving toward (or away from) a child with ASD. Error bars refer to standard errors of the mean (SEM).

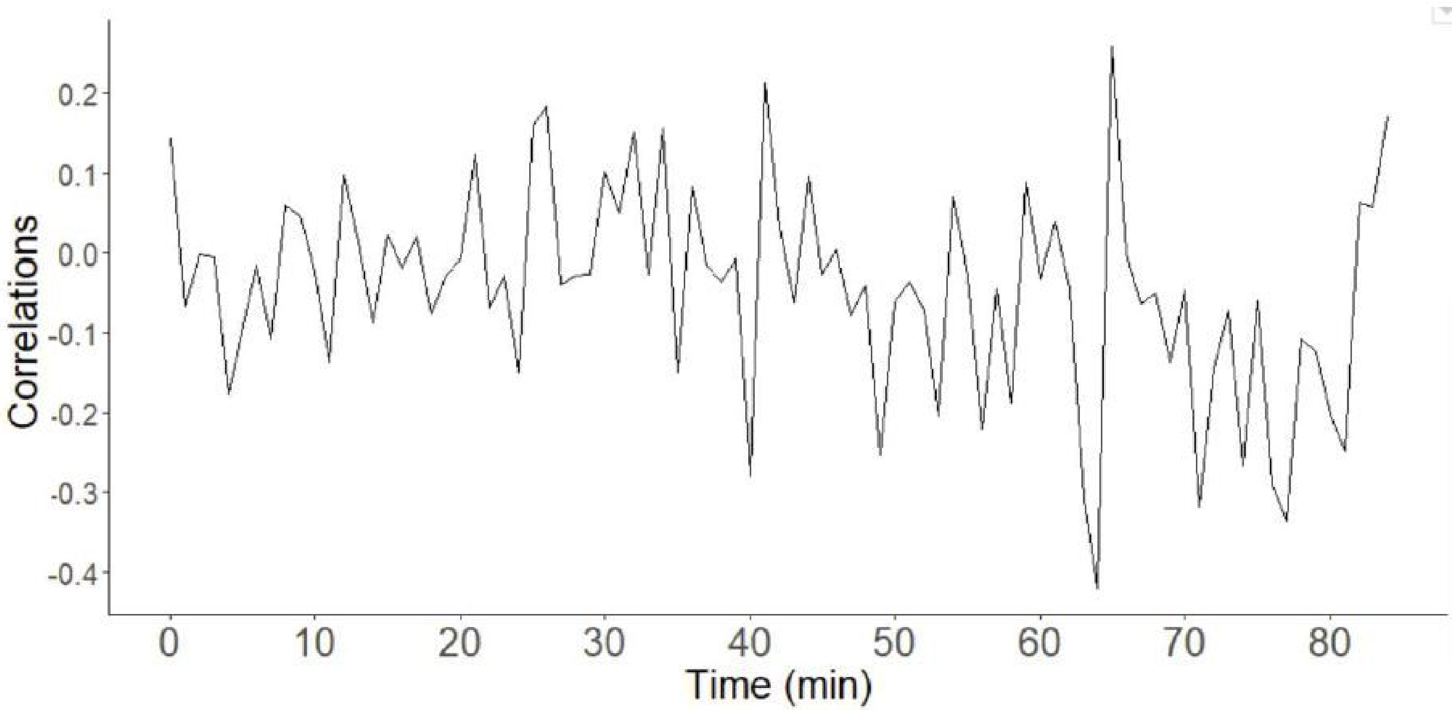


Figure 4

Correlated Social Approach Example. Note. Correlations of social approaches per minute calculated for 1 pair of children during one observation. For this pair of children, A and B, A's approach to B and B's approach to A are correlated at one minute intervals. The values of these correlations change rapidly and are plotted over 85 minutes.

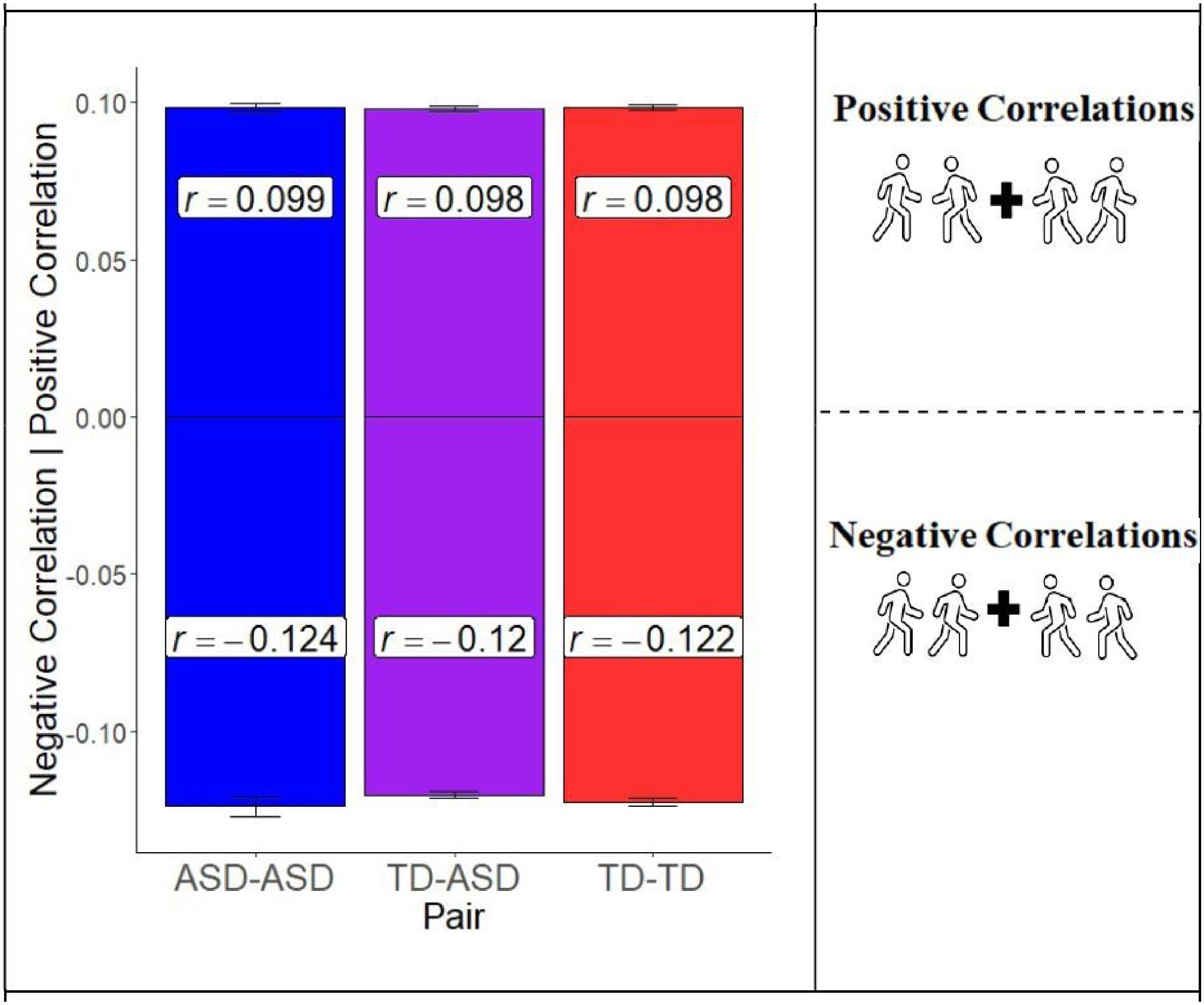
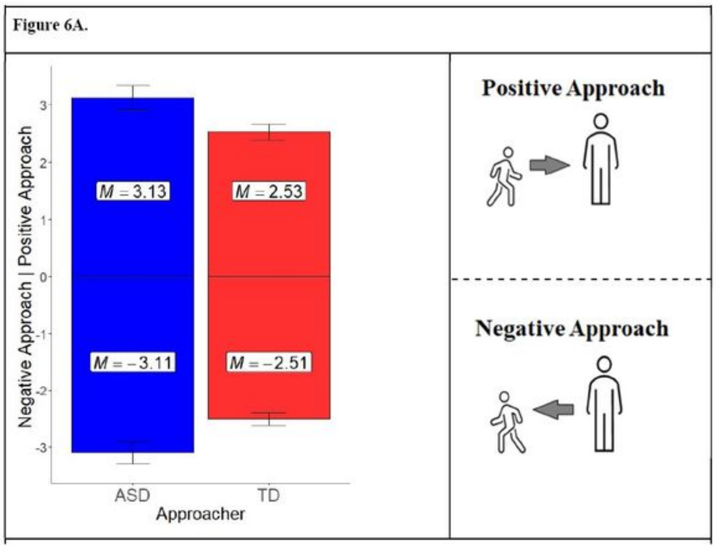


Figure 5

Correlated Peer Social Approach. Note. Correlations of paired peer social approaches per minute. Positive correlations refer to concordant approaches, where both members of the pair are moving toward or away from each other. Negative correlations occur when the child moves toward the partner and the partner moves away from that child (or vice-versa). Error bars refer to SEM.



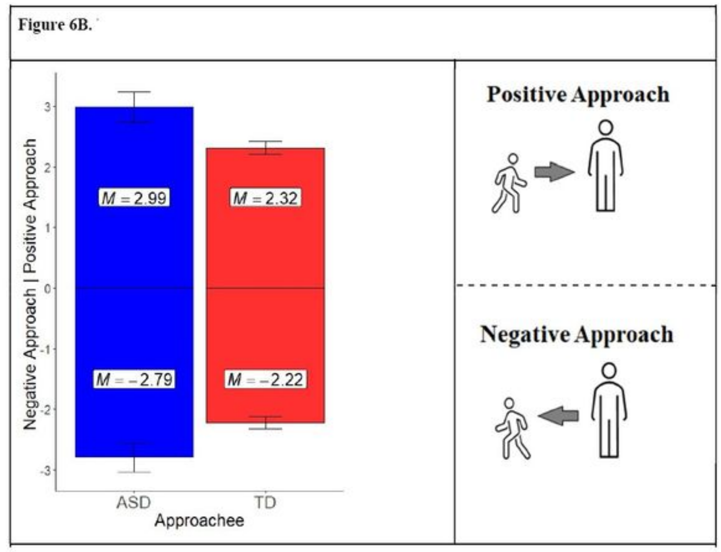


Figure 6

6A. Child Teacher Social Approach. Note. Approach is measured in cm/s. Positive approach indicates a child moving toward a teacher. Negative approach indicates a child moving away from a teacher. Error bars refer to SEM. 6B. Teacher Child Social Approach. Note. Approach is measured in cm/s. Positive approach indicates a teacher moving toward a child. Negative approach indicates a teacher moving away from a child. Error bars refer to SEM.

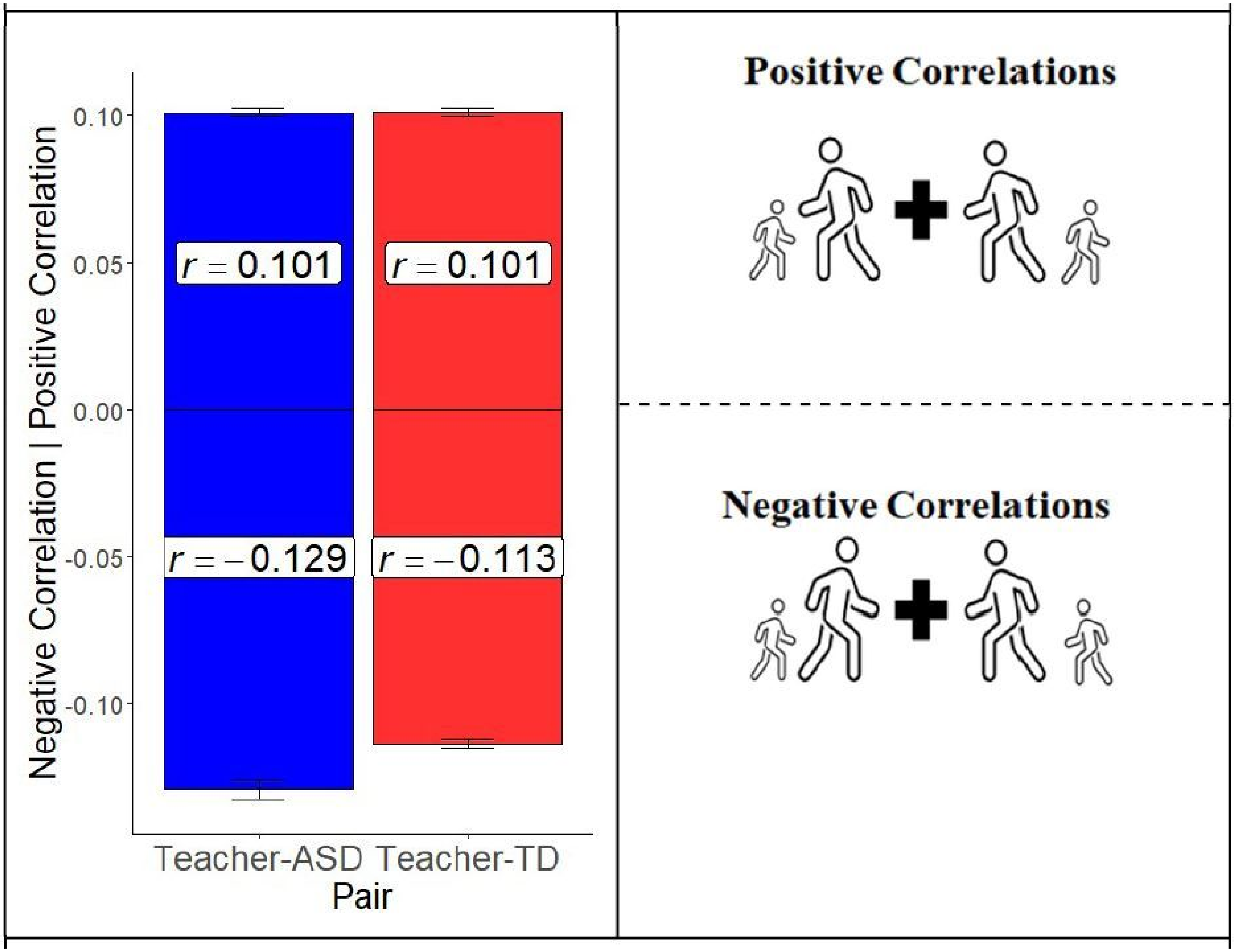


Figure 7

Correlations of Child-Teacher Social Approach. Note. Correlations of paired social approaches of children with teachers. Error bars refer to SEM.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- table1.pdf
- table2.pdf
- table3.pdf
- table4.pdf
- table5.pdf