Original Research Article

Interpersonal Synchrony and Affiliation in Children: A Transdiagnostic Approach

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Claire Bowsher-Murray[1,2], Elisabeth von dem Hagen[1,2,3,†] and Catherine RG Jones[1,2,†]

Abstract

Social partners often co-ordinate their non-verbal behaviour in time, leading to interpersonal synchrony (IPS). IPS is known to positively influence neurotypical children's assessment of affiliation between social partners, but it is unclear whether IPS informs the social judgements of children who are not neurotypical. Children aged 4 to 8 years identified as experiencing emotional, behavioural and/or cognitive difficulties ($N = 136$) completed a computer-based task in which they listened to tapping interactions between social partners. The simultaneity and regularity of partner tapping was independently manipulated. Participants rated partner affiliation and the 'togetherness' of partner tapping. Parents reported on children's: emotional and behavioural difficulties, autistic traits and inattention/hyperactivity. IPS did not significantly influence affiliation judgements across the sample as a whole. However, when analysed by gender, regularity (but not simultaneity) positively influenced boys' perceptions of partner affiliation, whereas simultaneity (but not regularity) positively influenced girls' affiliation judgements. Sensitivity to the social effects of IPS was not associated with parent-reported levels of difficulties or neurodivergent traits. Overall, children identified as experiencing emotional, behavioural and/or cognitive difficulties showed limited sensitivity to the social effects of IPS. Further research is required to understand the factors that explain variation in sensitivity to IPS as a social cue.

Lay Abstract

When we interact with another person we often co-ordinate our non-verbal behaviours, including gestures and movements, together in time. This is called interpersonal synchrony. Interpersonal synchrony positively influences typically developing children's assessment of affiliation between two people who are interacting with one another. However, we do not know if interpersonal synchrony informs the social judgements of children who are not typically developing. Children aged 4 to 8 years identified as experiencing emotional, behavioural and/or cognitive difficulties ($N = 136$) completed a computer-based task in which they listened to tapping interactions between social partners. We manipulated how 'together', or synchronised, the social partners tapped. Participants rated partner affiliation and the 'togetherness' of partner tapping. Parents completed questionnaires that provided information on their children's emotional and behavioural difficulties, autistic traits and inattention/hyperactivity. Interpersonal synchrony did not significantly influence affiliation judgements across the sample as a whole. However, when analysed by gender, limited but different effects of interpersonal synchrony on affiliation were found for boys and girls separately. Sensitivity to the social effects of interpersonal synchrony was not associated with parent-reported levels of difficulties or neurodivergent traits. Overall, children identified as experiencing emotional, behavioural and/or cognitive difficulties showed limited sensitivity to the social effects of interpersonal synchrony. Further research is required to understand the factors that explain variation in sensitivity to interpersonal synchrony as a social cue.

[1]Wales Autism Research Centre, School of Psychology, Cardiff University, Cardiff, UK
[2]Centre for Human Developmental Science, School of Psychology, Cardiff University, Cardiff, UK
[3]School of Psychology, Cardiff University Brain Imaging Research Centre, Cardiff, UK

[†]Catherine RG Jones and Elisabeth von dem Hagen share senior authorship.

Corresponding Author:
Catherine RG Jones, Wales Autism Research Centre, School of Psychology, Cardiff University, Park Place, Cardiff CF10 3AT, UK.
Email: jonescr10@cardiff.ac.uk

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During social interactions social partners often co-ordinate their non-verbal behaviour in time, leading to interpersonal synchrony (IPS) (Bernieri et al., 1988; Delaherche et al., 2012; Feldman, 2007). In neurotypical populations, IPS is a mechanism through which social bonds are built and understood (Hoehl et al., 2021; Rauchbauer & Grosbras, 2020). There is growing evidence that reduced IPS may be a transdiagnostic feature of populations in which differences or difficulties with social communication are prevalent (Chen et al., 2022; Fitzpatrick et al., 2017; Gvirts Problovski et al., 2021; Khalil et al., 2013; Lense et al., 2021; Marsh et al., 2013; Zampella et al., 2020). However, less is known about whether and to what extent IPS holds social relevance within such populations.

In neurotypical populations, increased IPS is associated with increased partner affiliation (Hove & Risen, 2009; Howard et al., 2021; Rabinowitch et al., 2015; Tarr et al., 2015, 2016; Tunçgenç & Cohen, 2016; Valdesolo & Desteno, 2011) and increased partner-directed prosocial behaviour (Rabinowitch & Meltzoff, 2017a, 2017b; Tunçgenç & Cohen, 2018). Using observational paradigms, the positive social effects of IPS have been observed in infants as young as 12 months (Cirelli et al., 2014, 2018; Fawcett & Tunçgenç, 2017; Tunçgenç et al., 2015).

There are different ways in which partners' actions may be temporally related. Actions may be simultaneous (i.e. partner behaviours co-occur in time), regular (i.e. there is temporal contingency between partners' behaviour), or both. Most previous studies examining the social effects of IPS have conceptualised IPS as requiring either one or both of these temporal components, without testing their separable effects on affiliation. Consequently the specific mechanism(s) underpinning the social effects of IPS are not well understood (Wan & Zhu, 2022). In a first study to explore whether simultaneity, regularity, or both, constitute the 'active ingredient' in the social effects of IPS in neurotypical children, Bowsher-Murray et al. (2023) found that simultaneity and regularity each affected the extent to which partners were perceived as affiliated. These relations were mediated by a perception of partner 'togetherness'. Thus, for neurotypical children, temporal interdependence appears to connote a sense of social connection, supporting theoretical accounts in which IPS is said to promote affiliation by fostering a sense of partner co-operation and shared intentionality (Kirschner & Tomasello, 2010; Reddish et al., 2013; Wan & Fu, 2019; Wan & Zhu, 2022).

IPS in Neurodivergent Populations

A growing body of research has explored IPS in neurodivergent populations, finding lower levels of IPS in interactions involving autistic children and adults (Chen et al., 2022; Fitzpatrick et al., 2017; Kruppa et al., 2021; Marsh et al., 2013; Zampella et al., 2020), relative to non-autistic individuals. There is also evidence of lower IPS in adults with ADHD (Gvirts Problovski et al., 2021), and evidence of an association between teacher-reported attentional difficulties and levels of IPS in children (Khalil et al., 2013). These findings have led some researchers to conclude that IPS is impaired in both autistic individuals and those with ADHD (e.g., Fitzpatrick et al., 2016; Gvirts Problovski et al., 2021; McNaughton & Redcay, 2020). However, a more nuanced approach would suggest that IPS may hold differing social significance across neurotypes (Bowsher-Murray et al., 2022), such that differences in IPS are better characterised as reflecting differing communication styles (Milton, 2012; Morrison et al., 2020) or 'misattunement' (Bolis et al., 2018) between neurotypes. Yet, to our knowledge, only two previous studies have investigated the social effects of IPS in non-neurotypical samples, both of which involved autistic adults. Unlike non-autistic individuals, autistic adults did not feel higher levels of empathy towards partners that they synchronised with in a computer-based task, compared to asynchronous partners. When measuring the tendency to perceive the social significance of IPS in others, autistic adults did not rate synchronous walkers as significantly higher in 'closeness' than asynchronous walkers. However, when asked to rank partners by closeness across all synchronous and asynchronous pairs presented, synchrony did affect their responses (Au & Lo, 2020), suggesting some influence of IPS on social judgements of others in autistic adults. Together with evidence of reduced behavioural IPS in neurodivergent populations, these studies suggest that the social effects of IPS may be reduced or absent for neurodivergent individuals.

Notably, the small number of previous studies that examined the social effects of IPS in neurodivergent samples all compared a single diagnostic group with neurotypical comparators. However, differences in, or difficulties with, social relationships and social communication are commonly observed across neurodivergent populations (Lense et al., 2021; Mikami et al., 2019; Missiuna et al., 2014). Despite commonalities within such populations, there may be more than one mechanism that influences how IPS is perceived and interpreted. For example, the

need for sustained social attention may present a challenge for children with high levels of inattention (Dahan et al., 2016; Harkins et al., 2022; Leitner, 2014), whereas higher levels of autistic traits may be associated with differences in interpreting non-verbal social cues. As such, neurodivergent traits might independently or interactively predict reduced social sensitivity to IPS. Yet, no previous studies on the social effects of IPS have explored the relative influence of co-occurring neurodivergent traits in the same sample. Therefore, to gain a broader insight into the way in which IPS is processed by those for whom social communication may be challenging, a transdiagnostic approach is needed. Specifically, instead of comparing social sensitivity to IPS in groups with and without neurodivergent diagnoses, it may be helpful to examine how social sensitivity to IPS is dimensionally related to neurodivergent traits, independent of formal diagnostic status.

The Present Study

In the present study, we assessed the social effects of IPS in a large sample of children identified via functional recruitment, that is, who were identified according to the presence of functional difficulties rather than diagnostic status (Astle et al., 2022). Children were eligible for inclusion if they were identified by their school as experiencing emotional, behavioural and/or cognitive difficulties (EB&CDs). First, using a task closely based on one previously completed by neurotypical children (Bowsher-Murray et al., 2023), we aimed to establish whether IPS, and/or particular temporal relations between partners (specifically, simultaneity and regularity), influence the affiliation judgements of children identified as experiencing EB&CDs. Second, we examined whether the relation between IPS and affiliation was mediated by a perception of partner 'togetherness'. Third, we explored whether sensitivity to IPS as a social cue was associated with overall levels of parent-reported emotional and behavioural difficulties, and/or neurodivergent traits, specifically, autistic traits and levels of inattention/hyperactivity.

Based on functional recruitment of a sample identified as experiencing EB&CDs, we predicted that sensitivity to IPS as a social cue would be reduced or absent in the sample as a whole. Furthermore, disrupted perceptions of partner 'togetherness' and/or a lack of association between perceived 'togetherness' and affiliation were expected. We predicted that lower sensitivity to IPS would be associated with higher levels of parent-reported difficulties and traits of neurodivergence.

Age and gender effects in the relation between IPS and affiliation in children identified as experiencing EB&CDs were also explored. Previous findings in neurotypical children (Bowsher-Murray et al., 2023) indicated that the affiliative effects of IPS increased with age. Comparable age effects were therefore predicted in children with EB&CDs. No gender differences in the effect of IPS on affiliation had been observed in neurotypical children (Bowsher-Murray et al., 2023). However, the symptom profiles of girls and boys identified as experiencing EB&CDs (see e.g. Maguire et al., 2016; Rescorla et al., 2007) and their identification by teachers (Soles et al., 2008) may differ. Therefore, we also explored whether gender influenced the relation between IS and affiliation in the current sample.

Material and Methods

Participants

One hundred and thirty-six participants (101 male; $M_{age} = 6$ years 7 months; $SD_{age} = 12$ months) were assessed at the Cardiff University Neurodevelopment Assessment Unit following referral from mainstream schools in South Wales. The Unit is focused on understanding and supporting children who are facing difficulties in the classroom but do not have a relevant diagnosis that would lead to specialist support. Children were eligible for inclusion if they were identified by their school as experiencing emotional, behavioural and/or cognitive difficulties. Children with a clinically diagnosed learning disability or neurodivergent diagnosis were not accepted for assessment, although those who had been referred for clinical assessment/diagnosis for a neurodevelopmental condition but were on a wait list for assessment were not excluded from participation. Many children in the sample fell into this latter category. The resulting cohort therefore consisted of children identified as exhibiting a variety of difficulties requiring additional support, and who were likely to display elevated levels of neurodivergent traits. Overall the sample was anticipated to contain a relatively high proportion both of children for whom either a clinical diagnosis might be received at a later date, and of children with relatively high but still subclinical levels of neurodivergent traits. Caregivers provided written informed consent on participants' behalf. The study was approved by the Cardiff University School of Psychology Research Ethics Committee.

Materials and Procedure

Participants completed the study task as part of a wider assessment of their socio-emotional, behavioural, and cognitive functioning. The full assessment battery was delivered over two days and took approximately five hours in total. Tasks were administered by a trained researcher in a dedicated testing room. The study task was completed on the second day of testing, that is after the researcher had engaged in extended informal and task-based interactions with the participant. The participant was only invited to complete the task in the current study if the researcher was confident that the participant was able to engage with the task, taking into account factors including the

participant's levels of verbal understanding, attention and fatigue. The participant's caregiver completed a range of questionnaires in a separate interview room.

IPS Task. The IPS task was designed to measure participants' sensitivity to IPS as a marker of affiliation between interacting partners. The task was a modified version of a task previously completed online by a neurotypical sample (Bowsher-Murray et al., 2023). The modifications were for in-person use. The task was presented in E-Prime 2.0 (Psychology Software Tools, 2012) on a laptop computer. Auditory stimuli were generated using Audacity®, version 3.0.2, https://audacityteam.org/. Before the task began, an example auditory stimulus was played. The volume was pre-set at 40% of the computer's maximum, then adjusted as necessary so it was comfortable for the participant. Task instructions were presented on screen and read aloud by the researcher, who controlled the pace of progress through the task. Participants answered task questions either verbally or by pointing to the relevant response box on the screen, and the researcher inputted the chosen response.

The task was designed to limit unwanted sources of variance in a neurodiverse sample. For example, stimuli were unimodal and the task included no motor demands, to exclude the influence of differential multisensory processing (e.g. de Boer-Schellekens et al., 2013; Noel et al., 2018; Stevenson et al., 2014) and synchronous motor behaviour (e.g. Ben-Pazi et al., 2016; Fitzpatrick et al., 2016; Kaur et al. 2018; Kruppa et al., 2021; Puyjarinet et al., 2017; Rubia et al., 2003) respectively.

Stimuli. Eight auditory stimuli, each of 11.5 s duration, were presented as recordings of two children playing a tapping game. In each series of taps, one child's 'taps' were made by a plastic beater striking a glockenspiel (G4, 392 Hz approx.), and the other by a finger pressing a piano key (C3, 131 Hz approx.). The simultaneity and regularity of tapping was manipulated across conditions (Table 1). In addition, each combination of simultaneity and regularity was presented both at a fast and slow basic tempo (500 and 800 ms, respectively). The tempo manipulation was used to provide variation in stimuli between trials, and also to explore whether effects were generalisable.

Procedure. In the first part of the task, participants were presented with a series of partner interactions in which aspects of IPS were manipulated, and rated the levels of affiliation between partners. In the task introduction, pictures of seven children were shown. The task instructions were: "*Here are some children. They are in the same class at school. One day, they played a game in pairs. Each pair made some sounds.*" It was explained that participants would hear the pairs of children playing and then answer some questions about the pair. An example pair of children (Figure 1(a)) was shown, with the glockenspiel sound ascribed to the child on the left and the piano sound ascribed to the child on the right.

Table 1. Temporal Relations Between Partner Taps.

	Simultaneous	Non-Simultaneous
Regular	Piano and glockenspiel simultaneous; both on the beat.	Piano on the beat. Glockenspiel later by 25% of the beat interval (fast trials = 125 ms; slow trials = 200 ms).
Irregular	Piano and glockenspiel simultaneous, but at varying intervals from the beat.	Piano and glockenspiel each at varying intervals from the beat; each varies independently from the other.

Note. Each combination of simultaneity/regularity was presented twice: once with a fast tempo (500 ms basic beat interval) and once with a slow tempo (800 ms basic beat interval). In line with the approach of Tarr et al. (2018), minor deviations (±2% of the beat interval) from the patterns indicated above were introduced, so that stimuli would more closely resemble an interaction produced by real tapping partners.

After the introduction, there were ten experimental trials. In each trial, two children of the same gender as the participant were shown (Figure 1(b)). Their faces were not visible. Children's 'names' were selected from the 80th to 100th most popular boys/girls names in Wales in 2012 (Office for National Statistics, 2013a, 2013b). There were 10 pairs of children, one of which was randomly selected without replacement for each trial. To further convey that the pictured children were interacting with each other, the photographs of the children were all taken in the same room (also the same room as the children taking part in the study). This was apparent from the background environment in the images, in which the same tables, chairs, door etc. were visible (Figure 1).

In eight of the ten trials, audio stimuli were presented as the sounds made by the pair shown. The remaining two trials represented a 'baseline' condition, in which no sounds were presented. As in other trials, the picture of the pair was displayed for 11.5 s, and participants were informed that the sounds made by the pair being displayed were not available. As no tapping interaction was heard in this condition, it served as a baseline measure of perceived affiliation between pairs (i.e. the affiliation judgements were not influenced by partners' temporal relation to each other).

At the end of each trial, participants answered two affiliation questions. The first question was: '*How much do you think* [names of children] *like each other?'* Response options were: '*Not at all*'; '*A little bit*'; '*Quite a lot*'; and '*Very much*' (Figure 1(d)). The second question was: '*At playtime, how often do you think* [names of children] *would choose the same toy to play with?'* Response options were: '*Never'*; '*Sometimes'*; '*Usually'*; and '*Always'*.

Figure 1. IPS Task: Overview of Procedure. *Note*. Participants Were Told They Would Hear Pairs of Children Who '*Made Some Sounds*' in a Tapping Game. After an Example Pair Was Pictured (a), There Were 10 Trials in Which a Pair of Children was Shown (b), and an Audio Track (in Which Simultaneity and Regularity Was Manipulated Across Trials) Was Presented, While the Images of the Children Remained Visible (c). The Participant Then Rated Affiliation Between the Pair (d) (Second Affiliation Question Not Shown). Subsequently, in the Second Part of the Task, Participants Listened Again to Each of the Eight Pairs Whose Interactions Were Not Heard (e), and Judged Whether They Sounded 'Together' or 'Not Together' (f). The Above Depiction of the Task is Modified From the Original as Images of Children Have Been Obscured for Anonymity.

The same ten trials were presented to each participant. There were two fixed orders, counterbalanced across participants, constructed so that the first five trials always included tapping interactions with all combinations of simultaneity/regularity described above, and a trial in which no interaction was heard. The order of conditions was otherwise selected randomly without replacement.

In the second part of the task, participants judged the 'togetherness' of partner tapping. For the eight trials in which an interaction was heard, each pair and associated sounds were presented again. The task instruction was: '*We want to know whether the children played their sounds together or not. We would say they played "together" if their sounds come at exactly the same time as each other*' (Figure 1(e)). Participants selected one of two response options: '*together*' or '*not together*' (Figure 1(f)), following which the next trial was presented.

Parent-Reported Difficulties and Neurodivergent Traits. The SDQ (Goodman, 1997) is a well-established screening tool for emotional and behavioural difficulties (Goodman, 2001; Goodman et al., 2000b). The present study used the parent-report version for children aged 4 to 17 years. There were 25 items, giving rise to four difficulty-related subscales (emotional symptoms; conduct problems; hyperactivity/inattention; peer relationship problems) and one related to strengths (prosocial behaviour). Example items included '*Often has temper tantrums or hot tempers*,' and '*Rather solitary, tends to play alone*'. Parents reported how true each item was of their child in the previous 6 months, on a three-point Likert scale: '*not true*'; '*somewhat true*'; '*certainly true*'. Five subscale scores (0–10) and a 'total difficulties' (0–40) score (the sum of the four difficulty-related subscales) were obtained by summing the four difficulty-related subscale scores. Higher scores indicated greater levels of difficulty, save for on the prosocial subscale in which higher scores indicated higher levels of prosociality. Cut off scores for each subscale and total score indicated whether, based on data from a United Kingdom community sample, scores were 'slightly raised' (80–90th percentile), 'high' (90–95th percentile) or 'very high' (>95th percentile).

The Autism Spectrum Quotient (Children's Version) (AQ-Child) (Auyeung et al., 2008) is a parent-report questionnaire used to measure autistic traits in children aged 4 to 11 years. There were 50 items (26 reverse scored) across five subscales (social skills; attention switching; attention to detail; communication; imagination). Example items

include '*Good at social chit-chat*' and '*Does not let others get a word in edgeways*'. Items were rated on a four-point Likert scale: '*definitely agree*'; '*slightly agree*'; '*slightly disagree*'; '*definitely disagree*'. Subscale scores (0–30) and a total score (0–150) were generated, with higher scores indicating higher levels of autistic traits. A total score of 76 or more is consistent with a diagnosis of autism at 95% specificity and sensitivity (Auyeung et al., 2008).

The Development and Well-Being Assessment (DAWBA) (Goodman et al., 2000a) assesses diagnostic traits from a number of disorders in the DSM-5 (American Psychiatric Association, 2013). The present study used the questionnaire items on the Attention and Activity Section (AAS) of the DAWBA only. Parents reported on their child's presentation in the previous six months. An initial question asked whether, taking into account the child's age, they '*definitely* [have] *some problems with overactivity or poor concentration*.' If the answer was no, a score of 0 was awarded. If the answer was yes, parents responded to a further 18 items, each corresponding to a characteristic of ADHD listed in the DSM-5. Nine items related to inattention (e.g. '*Is s/he easily distracted?*') and nine to hyperactivity/impulsivity (e.g. '*Is it hard for him/her to stay sitting down for long?*'). Parents rated whether the item applied to their child '*no more*', '*a little more*' or '*a lot more*' than other children of the same age, corresponding to scores of 0, 1 or 2 respectively. Two subscale scores (0–18) were calculated, one for the inattention items and one for the hyperactivity/impulsivity items, respectively, as well as a total score (0–36). As such, both the number and severity of inattention- and hyperactivity/impulsivity-related difficulties were reflected in the scores.

Statistical Analysis

Data were collated in Microsoft Excel and imported into IBM SPSS version 25.0 for statistical analysis.

Data Cleaning. Questionnaires with >10% of items missing were excluded from analysis, as a greater proportion of missing data would likely result in biased analysis (Bennett, 2001). For the AQ-Child, 16 participants (out of 121) had missing data at a rate of less than 10%. Little's Missing Completely at Random (MCAR) analysis (Little, 1988) indicated these data were missing completely at random ($\chi^2(706) = 728.14$, $p = .27$). Missing item scores were replaced by the mean value of the available items in the same subscale. No participants had incomplete data for the SDQ, DAWBA(AAS), or IPS task.

Parent-Reported Difficulties and Neurodivergent Traits. Descriptive statistics were used to characterise the type and degree of emotional and behavioural difficulties, levels of autistic traits and traits of inattention/hyperactivity in the sample as a whole. As not all questionnaire data was normally distributed, Spearman's Rank correlations were used to assess the interrelations between parent-reported difficulties and neurodivergent traits. Mann-Whitney U tests were used to assess gender differences in parent-reported difficulties and in neurodivergent traits.

IPS Task. For both affiliation questions, responses were converted to scores between 1 and 4 (higher values = greater liking/similarity). Scores for questions 1 (liking) and 2 (similarity) were positively associated, $r_s(1360) = .52$, $p < .001$. There was no difference in the pattern of results when questions 1 and 2 were treated as separate outcome variables, so the mean of the two scores was used as single outcome variable, 'affiliation score'. Mean scores in the fast (ISI 500 ms) and slow (ISI 800 ms) conditions were not significantly different, $t(136) = 1.70$, $p = .09$, so affiliation scores were collapsed across tempo.

Data were inspected for compliance with the assumptions for parametric testing. Q-Q plots indicated that affiliation scores were normally distributed within each cell. Greenhouse-Geisser corrections were applied as needed. A repeated measures ANOVA compared affiliation across three conditions in which tapping was: (a) fully synchronous (i.e. both simultaneous and regular); (b) fully asynchronous (i.e. both asynchronous and irregular); and (c) the baseline condition in which no interaction was heard. A further repeated measures ANOVA compared the separable effects of simultaneity and regularity on affiliation scores. Bonferroni-corrected post-hoc analysis was carried out as appropriate. To explore whether gender moderated the effect of simultaneity and/or regularity on affiliation judgements, a mixed ANOVA was constructed with gender as a between-subjects factor, and simultaneity and regularity as within-subjects factors.

To assess whether simultaneity and regularity influenced the likelihood of tapping being perceived as 'together', a generalised linear mixed model (GLMM) with a binomial distribution was constructed with simultaneity, regularity and a simultaneity x regularity interaction term as dummy-coded binary predictor variables and perceived togetherness as the binary outcome variable. To investigate whether participants' subjective perceptions of togetherness influenced their affiliation judgements, a further GLMM was constructed with perceived 'togetherness' as a single dummy-coded binary predictor variable and affiliation score as the outcome variable.

Participants' sensitivity to synchrony when making affiliation judgements was quantified using difference scores, which were calculated by subtracting each participant's affiliation score in the fully asynchronous condition from their score in the fully synchronous condition. The size of the difference score indicated the extent to which participants were influenced by the synchrony manipulation when judging affiliation, with a larger score indicating they were more influenced by IPS. Correlations investigated the

relation between sensitivity to synchrony and (i) age (ii) levels of parent-reported difficulties/neurodivergent traits as assessed by parent-report questionnaires.

Finally, a series of GLMMs investigated whether the relation between simultaneity/regularity and affiliation scores depended on levels of parent-reported difficulties and/or neurodivergent traits. The predictors in each GLMM were: a single experimental manipulation (simultaneity or regularity); one of the parent-report measure total scores; and an interaction term. Affiliation score was the outcome variable in all models. Analysis did not detect any interaction between simultaneity and regularity in their effects on affiliation, so the moderating role of parent-reported difficulties/neurodivergent traits was assessed separately for simultaneity and for regularity. Because levels of difficulties/neurodivergent traits on each measure were associated with one another with medium to large effect sizes, separate GLMMs were constructed to examine the moderating effect of levels of total difficulties, autistic traits and inattention/hyperactivity. Participant was a random effects variable in all mixed models.

Results

Sample Characteristics: Parent-Report Measures

Scores for the SDQ, AQ-Child and DAWBA(AAS) are set out in Table 2. Consistent with expectations, the sample was characterised by elevated levels of parent-reported emotional and behavioural difficulties: 83.7% of participants were reported as having total difficulties on the SDQ that were categorised as either 'slightly raised', 'high' or 'very high', with mean total difficulties in the 'very high' range.

There was substantial variability within the sample in the scores on each measure. All measures were positively correlated, with medium to large effect sizes (SDQ/AQ-Child: $r_s(121) = .48$, $p < .001$; SDQ/DAWBA(AAS): $r_s(131) = .55$, $p < .001$; AQ-Child/DAWBA(AAS): $r_s(119) = .34$, $p < .001$). Conduct difficulties, as assessed by the SDQ, were significantly higher in girls (mean rank = 81.8) than boys (mean rank = 63.2), $U = 2232$, $z = 2.43$, $p = 0.02$. Total difficulties on the SDQ were also significantly higher in girls (mean rank = 82.6) than boys (mean rank = 62.9), $U = 2261$, $z = 2.57$, $p = 0.01$. On the attention to detail subscale of the AQ-Child, boys (mean rank = 64.8) scored significantly higher than girls (mean rank = 49.3), $U = 1016$, $z = -2.10$, $p = 0.04$. There were no other significant effects of gender.

Effect of Fully Synchronous Tapping on Affiliation Scores

Affiliation scores were compared across the three conditions in which partners' tapping was: (a) fully synchronous (i.e. both simultaneous and regular), (b) fully asynchronous (i.e. neither simultaneous nor regular), or (c) not heard (the baseline condition). A one-way repeated measures ANOVA revealed that affiliation scores were significantly different across conditions, $F(1.88, 253.08) = 10.43$, $p < .001$, $\eta^2 = .07$. (Figure 2(a)). Post-hoc analysis indicated that affiliation scores were significantly higher in both conditions in which partner tapping was heard compared to the baseline condition (fully synchronous: $p < .001$; fully asynchronous: $p = .01$). However, there was no significant difference between affiliation scores in the fully synchronous and fully asynchronous conditions ($p = .49$). When the analysis was repeated separately for boys (Figure 2(b)) and girls (Figure 2(c)), the same pattern of findings was observed but the difference between the baseline and other conditions was only significant in boys.

To investigate the strength of the evidence in favour of the key finding that there was a non-significant difference in affiliation scores in the fully synchronous and fully asynchronous conditions, we compared affiliation scores in those two conditions again using a Bayesian paired *t*-test. This analysis yielded a Bayes Factor of 5.59, indicating moderate evidence (Jeffreys, 1961) in favour of the null hypothesis, that is that there was no difference in affiliation scores in the fully synchronous and fully asynchronous conditions.

The Separable Effects of Simultaneity and Regularity on Affiliation Scores

Mean affiliation scores were 2.81 ($SD = 0.75$) for simultaneous tapping and 2.76 ($SD = 0.76$) for non-simultaneous tapping (collapsed across regularity). Mean affiliation scores were 2.81 ($SD = 0.78$) for regular tapping and 2.76 ($SD = 0.72$) for irregular tapping (collapsed across simultaneity). A two-way repeated measures ANOVA revealed that neither simultaneity, $F(1,135) = 0.86$, $p = .36$, $\eta_p^2 = .006$, nor regularity, $F(1,135) = 1.17$, $p = .28$, $\eta_p^2 = .009$ had a significant effect on affiliation scores in the sample as a whole (Figure 3(a)). The interaction between simultaneity and regularity was also non-significant, $F(1,135) = 0.05$, $p = .83$, $\eta_p^2 < .001$.

To explore whether gender moderated the effect of simultaneity and/or regularity on affiliation judgements, a mixed ANOVA was constructed with gender as a between-subjects factor, and simultaneity and regularity as within-subjects factors. There was no main effect of simultaneity, $F(1,134) = 3.42$, $p = .07$, $\eta_p^2 = .03$ or regularity $F(1,134) = 0.02$, $p = .89$, $\eta_p^2 < .001$, nor an interaction between simultaneity and regularity, $F(1,134) = 0.09$, $p = .77$, $\eta_p^2 = .001$. However, there was a significant two-way interaction between gender and simultaneity, $F(1,134) = 4.48$, $p = .04$, $\eta_p^2 = .03$, and between gender and regularity, $F(1,134) = 5.11$, $p = .03$, $\eta_p^2 = .04$.

The effects of simultaneity and regularity on boys' and girls' affiliation judgements were therefore explored

Table 2. Descriptive Statistics for Parent-Report Measures.

Measure	Subscale	Mean (*SD*)			Min-max; cut-off
		Boys	Girls	Total	
	N	*100*	*35*	*135*	
SDQ	Emotional	4.6 (*2.5*)	5.4 (*3.0*)	4.8 (*2.7*)	0–10; 5
	Conduct	4.4 (*2.6*)	5.6 (*2.6*)	4.7 (*2.7*)	0–10; 4
	Hyperactivity	8.1 (*2.4*)	8.7 (*2.2*)	8.3 (*2.4*)	0–10; 8
	Peer	3.8 (*2.1*)	4.3 (*2.4*)	3.9 (*2.2*)	0–10; 4
	Prosocial	6.1 (*2.6*)	5.8 (*3.0*)	6.1 (*2.7*)	0–10; 6
	Total Difficulties	20.8 (*6.7*)	24.0 (*7.2*)	21.6 (*6.9*)	0–40; 17
	N	*91*	*30*	121	
AQ-	Social Skills	15.6 (*6.4*)	15.2 (*6.2*)	15.5 (*6.3*)	0–30
Child	Attention Switching	19.7 (*5.9*)	18.4 (*5.6*)	19.4 (*5.8*)	0–30
	Attention to Detail	16.3 (*5.9*)	13.8 (*5.3*)	15.7 (*5.8*)	0–30
	Communication	18.9 (*5.2*)	19.3 (*6.5*)	19.0 (*5.5*)	0–30
	Imagination	13.6 (*5.2*)	13.7 (*6.0*)	13.6 (*5.5*)	0–30
	Total	84.1 (*22.3*)	80.3 (*24.2*)	83.2 (*22.7*)	0–150; 76
	N	*98*	*33*	*131*	
DAWBA	Inattention	12.4 (*5.2*)	11.7 (*6.1*)	12.3 (*5.4*)	0–18
(AAS)	Hyperactivity/Impulsivity	13.0 (*5.7*)	12.5 (*6.4*)	12.9 (*5.8*)	0–18
	Total	25.5 (*10.4*)	24.2 (*12.3*)	25.1 (*10.8*)	0–36

Note. SDQ = Strengths and Difficulties Questionnaire; AQ-Child = Autism Spectrum Quotient (Children's Version); DAWBA(AAS) = Development and Well-Being Assessment (Attention and Activity Section). Higher scores indicate higher levels of difficulty/traits, save for on the SDQ prosocial subscale, on which higher scores indicate higher prosociality. Quoted SDQ 'cut-off' scores represent a 'high' level of difficulty (ie in the 90th + percentile at a population level). *N* = number of participants for whom parent-report data was included in analysis, which varies by measure because not all questionnaires were completed for each participant.

separately using two-way repeated measures ANOVA. For **boys** (Figure 3(b)), there was a main effect of regularity on affiliation score, $F(1,101) = 4.51$, $p = .04$, $\eta_p^2 = .04$, with regular tapping ($M = 2.85$; $SD = 0.81$) attracting significantly higher affiliation scores than irregular tapping ($M = 2.74$; $SD = 0.76$). Conversely, for **girls** (Figure 3(c)), there was a main effect of simultaneity on affiliation score, $F(1,35) = 4.80$, $p = .04$, $\eta_p^2 = .12$, with simultaneous tapping ($M = 2.86$; $SD = 0.63$) attracting significantly higher affiliation scores than non-simultaneous tapping ($M = 2.64$; $SD = 0.67$). No other main effects or interactions were significant for either gender (all other p's $> .19$).

Perceived 'Togetherness' of Tapping

Figure 4 indicates the frequency with which tapping was perceived as together for each combination of simultaneity and regularity. A GLMM indicated that simultaneity ($\beta = 0.91$, $t = 4.74$, $p < .001$) and regularity ($\beta = 0.71$, $t = 3.74$, $p < .001$) each had a significant positive effect on the likelihood of perceiving tapping as 'together'. The interaction between simultaneity and regularity was non-significant ($\beta = 0.03$, $t = 0.13$, $p = .90$). A further GLMM indicated that tapping perceived as 'together' ($M = 2.90$) attracted significantly higher affiliation scores than tapping

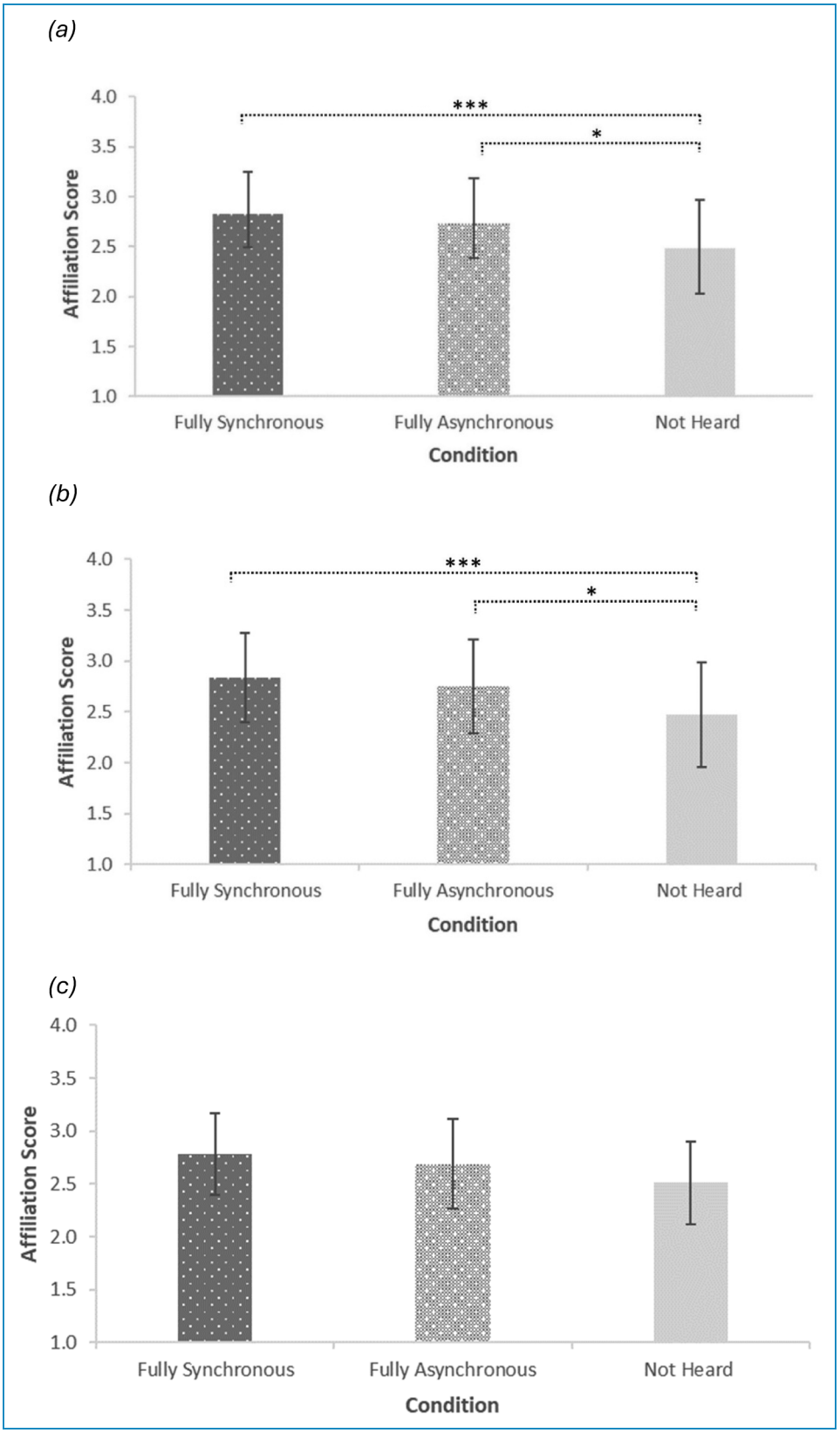

Figure 2. Effect of Fully Synchronous Tapping on Affiliation Scores in the Sample as a Whole and by Gender. (a) Whole Sample. (b) Boys. (c) Girls. *Note.* 'Fully Synchronous' = Simultaneous and Regular Tapping; 'Fully Asynchronous' = Tapping Neither Simultaneous Nor Regular. Min. Score = 1; Max. Score = 4; Higher Scores Indicate Greater Affiliation. Error Bars Indicate Standard Deviation. *$p < .05$. ** $p < .01$. *** $p < .001$.

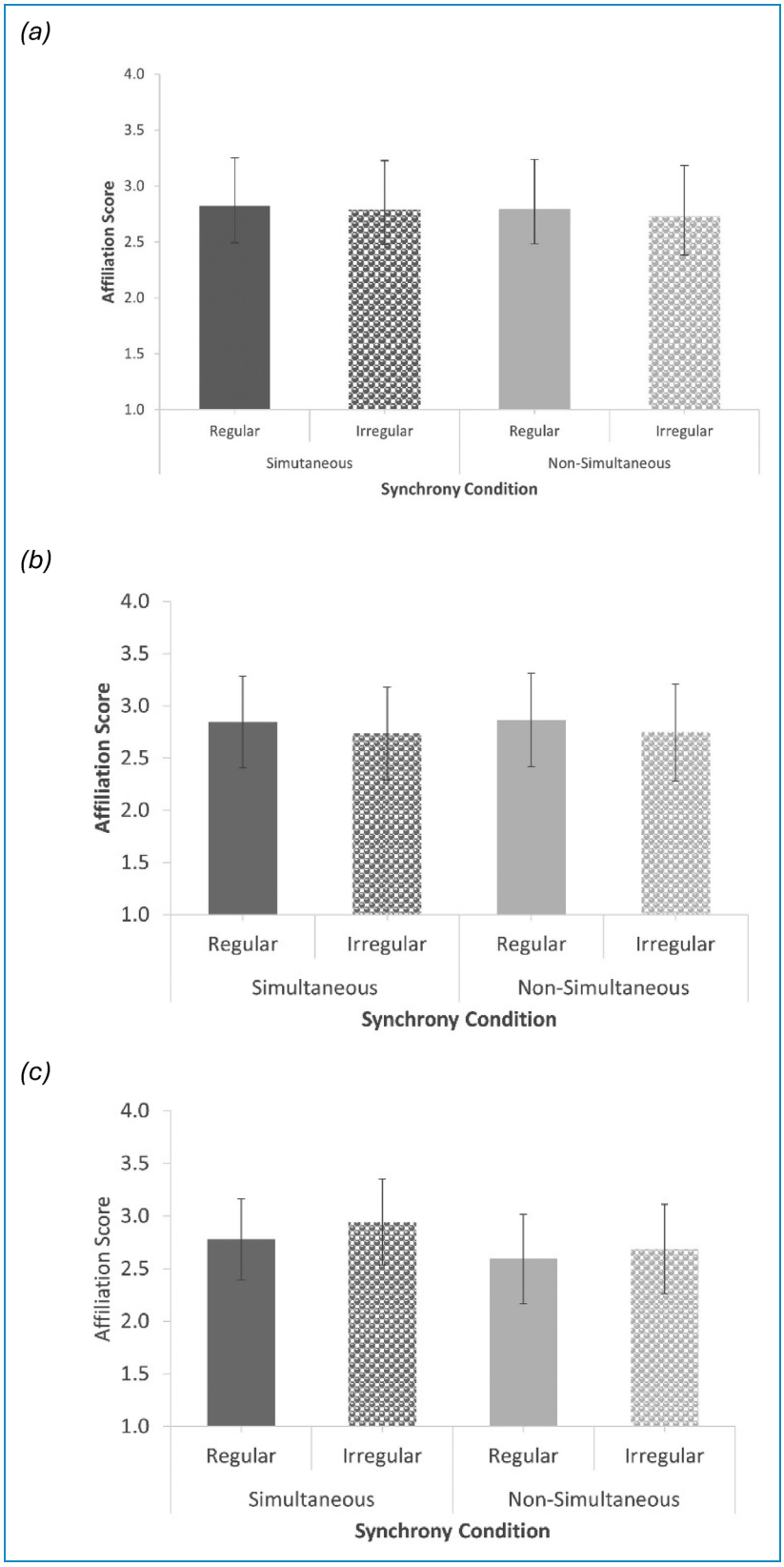

Figure 3. Mean Affiliation Scores for Each Combination of Simultaneity and Regularity in the Sample as a Whole and by Gender. (a) Whole Sample. (b) Boys. (c) Girls. *Note.* Min. Score = 1; max. Score = 4; Higher Scores Indicate Greater Affiliation. Error Bars Indicate Standard Deviation.

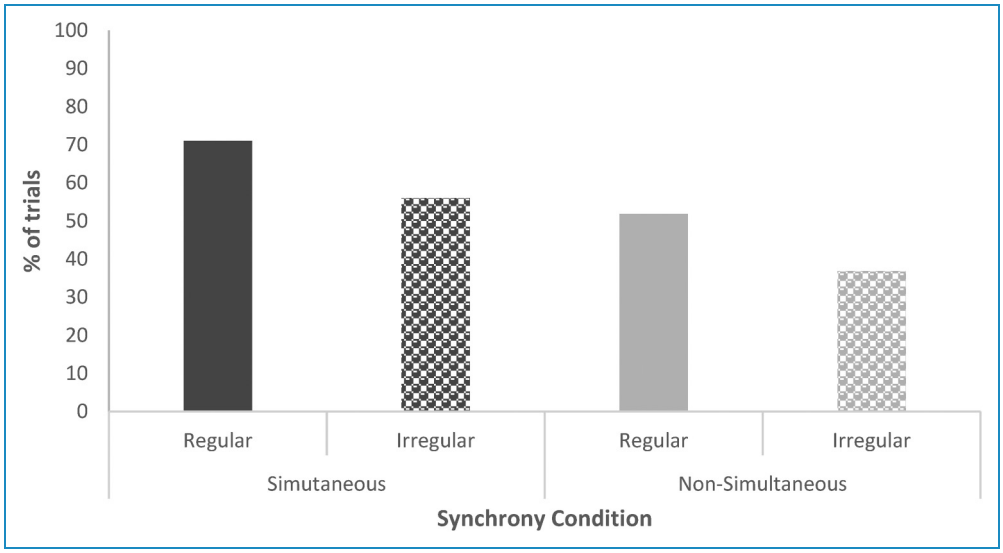

Figure 4. Percentage of Trials in Which Tapping Was Perceived as 'Together', by Synchrony Condition.

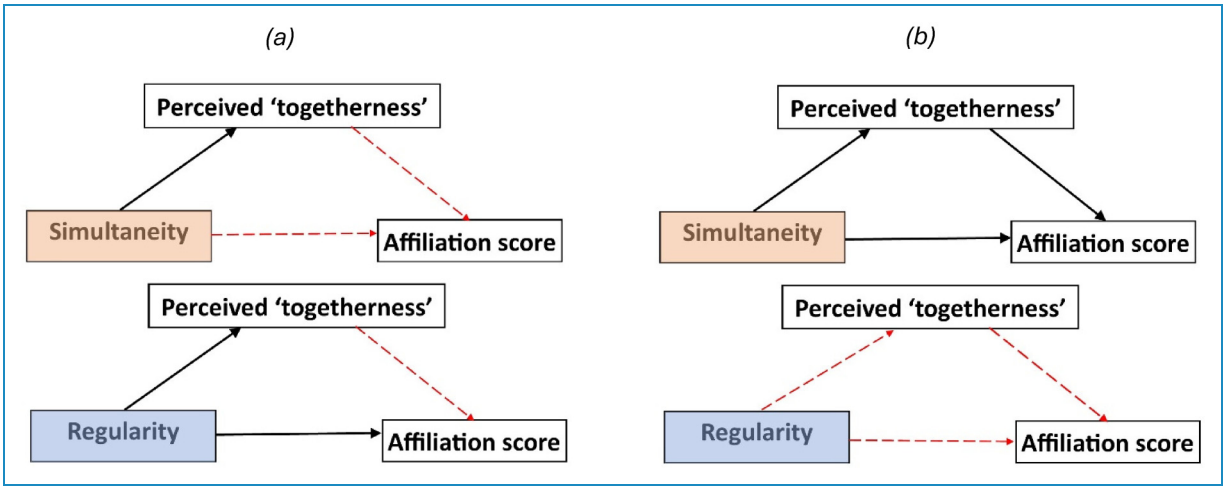

Figure 5. Relations Between Simultaneity/Regularity, Togetherness and Affiliation in Boys and Girls. (a) Boys. (b) Girls. *Note.* Solid Black Arrows Denote Significant Pathway; Dotted Red Arrows Denote Non-Significant Pathway.

perceived as 'not together' ($M = 2.68$) ($\beta = 0.13$, $t = 2.03$, $p = .04$).

To assess gender differences in the potential mediating role of 'togetherness' on perceived affiliation, gender differences in the relation between simultaneity/regularity and perceived togetherness were explored. Two separate GLMMs (one for boys and one for girls) were constructed with simultaneity, regularity and a simultaneity x regularity interaction term as dummy-coded binary predictor variables and perceived togetherness as the binary outcome variable. For **boys**, simultaneity ($\beta = 0.77$, $t = 3.47$, $p < .001$) and regularity ($\beta = 0.72$, $t = 3.26$, $p < .001$) each had a significant positive effect on the likelihood of perceiving tapping as 'together'. For **girls**, only simultaneity had a significant positive effect on the likelihood of perceiving tapping as together ($\beta = 1.37$, $t = 3.48$, $p < .001$). No other main effects or interactions were significant in boys or in girls.

Finally, gender differences in the relation between perceived togetherness and affiliation scores were explored with two separate GLMMs, in which perceived 'togetherness' was a single dummy-coded binary predictor variable and affiliation score was the outcome variable. In **boys**, perceived 'togetherness' did not significantly predict affiliation score ($\beta = 0.13$, $t = 0.67$, $p = .50$), but in **girls**, tapping perceived as 'together' predicted significantly higher affiliation scores than tapping perceived as 'not together' ($\beta = 0.43$, $t = 3.17$, $p = .002$). The relations between simultaneity/regularity, perceived togetherness and affiliation in boys and girls are summarised in Figure 5.

Effect of Age

Overall sensitivity to synchrony, represented by each participant's difference score (i.e. mean affiliation score across simultaneous and regular trials minus mean affiliation score across non-simultaneous and irregular trials), was not significantly associated with age in boys, $r(101) = -.01$, $p = .90$, in girls, $r(35) = -.02$, $p = .86$, or in the sample as a whole, $r(136) = -.14$, $p = .44$.

Relations With Parent-Reported Difficulties/ Neurodivergent Traits

As the effects of simultaneity and regularity on affiliation were moderated by gender, the relations between parent-reported difficulties/neurodivergent traits and sensitivity to IPS (as quantified by participants' difference scores) was investigated in the sample as a whole and for boys and girls separately (Table 3). No significant associations between difficulties/neurodivergent traits and sensitivity to IPS were identified.

Finally, there were no significant interactions between simultaneity/regularity and any of the questionnaire measures in predicting affiliation scores, either in the sample as a whole or in boys and girls separately (see Supplemental Materials Tables 1 and 2). Thus the relations between simultaneity and affiliation score and between regularity and affiliation score were not moderated by total levels of parent-reported difficulties or neurodivergent traits.

Discussion

The current study is the first transdiagnostic investigation of children's sensitivity to IPS when making affiliation judgements about interacting partners. In a functionally recruited sample of children identified as experiencing emotional, behavioural and/or cognitive difficulties, in the sample as a whole there was no significant relationship between IPS and perceived affiliation. However, effects differed by gender, with affiliation judgements being positively influenced by regularity in boys and by simultaneity in girls, but not vice versa. This contrasts with a previous study of IPS in neurotypical children, where both regularity and simultaneity conferred affiliative effects regardless of gender (Bowsher-Murray et al., 2023). Children's social sensitivity to IPS was unrelated to their levels of parent-reported difficulties, autistic traits, or levels of inattention and hyperactivity. Overall, IPS appears to be of relatively limited social significance for children identified as experiencing EB&CDs, but it remains unclear what accounts for variation in social sensitivity to IPS within this population.

Findings in the Sample as a Whole

At a whole sample level, we found no direct relation between IPS and perceptions of affiliation between interacting partners in children identified as experiencing EB&CDs. As expected, parents reported high levels of autistic and ADHD traits in the sample, along with other differences captured by the SDQ. This result contrasts with previous findings in neurotypical children obtained using a similar paradigm (Bowsher-Murray et al., 2023), in which IPS had medium to large effects on neurotypical children's affiliation judgments. This previous study used children with a broader age range (4–11 years) and the data were collected online, with pre-recorded experimenter instructions, rather than in person. Thus, direct comparison of the two studies is not possible. However, the positive findings in the previous study established that the task can robustly elicit the affiliative effects of IPS and that these effects are characteristically found in neurotypical children. The current findings also contrast with other previous findings that neurotypical infants (Cirelli et al., 2018; Fawcett & Tunçgenç, 2017) and children (Abraham et al., 2022) judge synchronous interactors as higher in affiliation than those who interacted asynchronously. As discussed, we found no overall effect of IPS on affiliation judgments in children identified as experiencing EB&CDs, suggesting lower social influence of IPS in these children. It is inherently difficult to draw conclusions from a null finding, as there may be a variety of reasons why no effect was detected in this study. However, this study was carefully designed to minimise the likelihood of alternative explanations, for example by using uni-sensory stimuli, minimising verbal task demands and closely monitoring participant attention and fatigue. Further, Bayesian analysis also suggested that there was moderate evidence for the key null finding that perceptions of affiliation in the sample as a whole were not influenced by the presence or absence of IPS. Thus, while our findings do provide support for the proposition that social sensitivity to IPS is not a robust phenomenon in children identified as experiencing EB&CDs, further research is needed to gain a clearer understanding of the social significance of IPS outside the context of neurotypical development.

Gender Differences in Sensitivity to IPS

In contrast to previous findings in neurotypical children (Bowsher-Murray et al., 2023), there were gender differences in the effects of IPS on the affiliation judgements of the present sample. In neurotypical children, the presence of simultaneity *or* regularity was enough to confer affiliative effects (Bowsher-Murray et al., 2023). By contrast, children identified as experiencing EB&CDs were sensitive to one but not both of these temporal qualities, depending on gender. For boys in this sample, perceptions of affiliation were positively influenced by regularity, but not simultaneity. 'Togetherness' did not mediate affiliative effects, suggesting a partial overlap in the temporal qualities that influence the affiliation judgements of boys with and

Table 3. Association Between Sensitivity to Interpersonal Synchrony (IPS) and Parent-Reported Difficulties/Neurodivergent Traits.

		r_s (*p*)		
Measure	Subscale	Boys	Girls	Total
N		*100*	*35*	*135*
SDQ	Emotional	−0.14 (*.16*)	−0.09 (*.62*)	−0.12 (*.16*)
	Conduct	0.13 (*.21*)	0.05 (*.75*)	0.10 (*.24*)
	Hyperactivity	0.06 (*.58*)	0.25 (*.15*)	0.11 (*.22*)
	Peer	0.05 (*.60*)	0.13 (*.44*)	0.07 (*.40*)
	Prosocial	−0.05 (*.63*)	−0.04 (*.82*)	−0.04 (*.66*)
	Total Difficulties	0.06 (*.58*)	0.07 (*.68*)	0.06 (*.49*)
N		*91*	*30*	*121*
AQ-	Social Skills	0.07 (*.53*)	0.20 (*.30*)	0.09 (*.30*)
Child	Attention Switching	−0.08 (*.48*)	0.06 (*.75*)	−0.05 (*.58*)
	Attention to Detail	−0.11 (*.28*)	0.15 (*.42*)	−0.06 (*.51*)
	Communication	0.04 (*.72*)	0.11 (*.55*)	0.06 (*.51*)
	Imagination	0.09 (*.40*)	0.17 (*.38*)	0.12 (*.19*)
	Total	−0.02 (*.87*)	0.21 (*.27*)	0.04 (*.66*)
N		*98*	*33*	*131*
Dawba	Inattention	0.04 (*.70*)	0.17 (*.38*)	0.07 (*.43*)
(AAS)	Hyperactivity/Impulsivity	0.12 (*.25*)	0.21 (*.27*)	0.14 (*.11*)
	Total	0.08 (*.43*)	0.14 (*.34*)	0.10 (*.27*)

Note. Sensitivity to IPS quantified using difference scores on IPS task (affiliation score for fully synchronous tapping minus affiliation scores for fully asynchronous tapping). SDQ = Strengths and Difficulties Questionnaire; AQ-Child = Autism Spectrum Quotient (Children's Version); DAWBA(AAS) = Development and Well-Being Assessment (Attention and Activity Section).

without EB&CDs, but different mechanisms by which such effects arise. In girls in the sample, the opposite pattern was observed: simultaneity, but not regularity, led to significantly higher affiliation ratings. For girls, simultaneity positively influenced perceptions of partner 'togetherness', which in turn positively influenced perceived affiliation. Thus, girls identified as experiencing EB&CDs performed similarly to their neurotypical peers when presented with simultaneous interactions, but did not display comparable effects for regularity. However, the findings in relation to girls must be interpreted with caution, as the smaller number of girls in the sample ($n = 35$) may have been underpowered to detect relevant effects. Overall, the data suggested that there were differences in the way boys and girls in the sample responded to IPS, but did not indicate that one gender was more sensitive to IPS as a social cue than the other. Both girls and boys in the sample displayed different responses to simultaneity and regularity, suggesting sensitivity to IPS as a social cue was attenuated but not absent in both genders. Notably, the girls in the present sample had significantly higher levels of parent-reported difficulties than the boys, although the lack of association between SDQ and affiliation score in either group means it is unlikely that this difference can explain the gender differences in the pattern of findings. Controlling for differences in levels of parent-reported difficulties in the analysis of

gender effects was not feasible because of the relatively small number of girls in the sample.

Previous research has found higher levels of IPS in females than males, in both neurotypical (Cheng et al., 2017; Fujiwara et al., 2019) and autistic (Paolizzi et al., 2022) samples, as well as some evidence of greater sensitivity to IPS as a social cue in neurotypical females (Fujiwara et al., 2019; Tschacher et al., 2014; although cf. Kirschner and Tomasello 2010; Cacioppo et al., 2014 and Bowsher-Murray et al., 2023 in which no such gender differences were found). Thus, in a gender-balanced sample, matched for levels of emotional and behavioural difficulties, it is possible that girls would display *greater* sensitivity to IPS as a social cue than boys. Because of the considerably uneven group sizes in our study, it is important to note that further research is required to understand the relation between gender and sensitivity to IPS as a social cue in children identified as experiencing EB&CDs, and in particular whether gender may be a protective factor for females.

Sensitivity to Other Social Aspects of the Stimuli

Although children identified as experiencing EB&CDs showed attenuated overall sensitivity to IPS, participants made other relevant social judgements based on the stimuli presented. They rated partners whose interactions were audible, regardless of (a)synchrony, as significantly higher in affiliation than those in the baseline condition (in which they did not hear an interaction). This suggests that the interaction itself conveyed a sense of affiliation between interacting partners, a pattern also found in a neurotypical sample (Bowsher-Murray et al., 2023). Similarly, other studies in neurotypical children also found that the presence of an interaction (irrespective of its temporal properties) led to increased levels of partner closeness (Rabinowitch et al., 2015) and prosocial behaviour (Rabinowitch & Meltzoff, 2017a), relative to a baseline condition in which no interaction took place. Therefore, when the manipulation was particularly salient (i.e. the occurrence or non-occurrence of an interaction), children identified as experiencing EB&CDs experienced similar social effects to neurotypical children. However, overall, they did not show the typical sensitivity based on the quality of interaction, specifically whether the interaction was synchronous or asynchronous. The fact that the task elicited such social effects would also tend to suggest that children understood and believed the premise of the task, that is they were able to impute that the auditory stimuli represented real interactions between the pictured children. Thus, the findings in relation to the baseline condition would tend to rule out a lack of task understanding/believability as an alternative explanation for the main findings in relation to the effects of simultaneity and regularity.

Relations Between Difficulties/Neurodivergent Traits and Sensitivity to IPS

This was the first study to examine whether parent-reported emotional and behavioural difficulties and/or neurodivergent traits were dimensionally associated with social sensitivity to IPS. Previous studies have found a dimensional relation between increasing levels of autistic traits and the incidence of IPS in interactions, in both child and adult samples drawn from diagnostic groups and the general population (Brezis et al., 2017; Cheng et al., 2017; Fitzpatrick et al., 2017; Romero et al., 2018; Zampella et al., 2020; Granner-Shuman et al., 2021; although cf. Kaur et al., 2018). Similarly, increased levels of inattention in a population-based child sample were associated with reduced levels of IPS (Khalil et al., 2013). Fewer studies have examined social sensitivity to IPS in neurodivergent populations, as distinct from the incidence of IPS in actual interactions. Two previous studies adopting a categorical approach found that the influence of IPS on social judgements was reduced or absent in autistic adults, relative to non-autistic comparators (Au & Lo, 2020). The association between behavioural traits and the production of IPS within an interaction led us to predict that such traits and social sensitivity to IPS between others would also be dimensionally related. However, contrary to this hypothesis, we found no evidence of a relation between sensitivity to IPS as a social cue and parent-reported difficulties or neurodivergent traits.

Although we found no relation between children's sensitivity to IPS as a social cue and their parent-reported difficulties or neurodivergent traits, there remains a possibility that such a link exists. For example, the current study used a simple and brief measure of affiliation between partners, which was two questions on a four-point Likert scale. Although this approach was necessary to ensure accessibility for young children identified as experiencing EB&CDs, particularly in the context of a longer testing session, a more detailed measure of individuals' sensitivity to IPS as a social cue might be needed to detect a relation with parent-reported difficulties and/or neurodivergent traits. For example, longer and/or a larger number of partner interactions, and more extended questionnaires measuring affiliation (see e.g. Lang et al., 2017; Tarr et al., 2016), would give rise to greater internal reliability and dimensionality in the measurement of affiliative effects.

A further consideration is that our measures of neurodivergent traits were parent-report questionnaires that were primarily designed to screen or signpost for the presence of a neurodevelopmental condition. There are multiple trait profiles that may meet the criteria for the same neurodevelopmental condition, and heterogeneous clusters of traits may give rise to comparable scores on instruments designed to measure the extent to which a person displays neurodivergent characteristics (Ameis, 2017; Astle et al., 2022;

Mareva et al., 2019; Márquez-Caraveo et al., 2021). As such, trait-based measures such as the ones used in the present study may be insufficiently sensitive to variation in the processes giving rise to variation in sensitivity to IPS. For example, in our measure of autistic traits we did not separately explore the two core domains of difference, social communication and restricted and repetitive behaviours, which can both be fractionated into further subtypes (e.g. Uljarević et al., 2020, 2021). Further, variation in social sensitivity to IPS may be more closely related to functioning that is not directly captured in measures of diagnostic traits. For example, a range of perceptual, motor and social processes likely contribute to the emergence and social effects of IPS (Bowsher-Murray et al., 2022), many of which may differ in neurodivergent populations compared to neurotypical populations (see e.g. Falter & Noreika, 2014; Frazier et al., 2021; Hudry et al., 2020; Harkins et al., 2022; Lense et al., 2021; Wallace & Stevenson, 2014) but not captured in measures of diagnostic traits. An alternative approach to explaining variation in social sensitivity to IPS might therefore investigate how children's abilities within the component processes of IPS map on their sensitivity to IPS when making social judgements.

Other factors that may play a role in children's synchrony-related social judgements include language and general cognitive ability. We did not measure either construct in the current study. Rather, we sought to minimise their influence on children's responses, for example by using simple task instructions and close monitoring and evaluation of children's understanding by the researcher. Future research might seek to quantify and measure and/or control for the influence of language and cognitive ability on children's responses to IPS.

Theoretical and Practical Implications

This is the first study to explore social sensitivity to IPS in children with EB&CDs. Thus, consideration of the theoretical and practical implications of the findings are necessarily tentative. However if, as our findings suggest, there is in fact a limited relation between IPS and affiliation judgements in children identified as experiencing EB&CDs, then there would be implications for their social functioning. IPS allows neurotypical children to understand social relations between others in a quick and intuitive way. Our findings suggest that this is not a robust phenomenon among children identified as experiencing EB&CDs, who are more likely to assess and integrate IPS-related social cues differently or not at all. This may have implications in everyday social settings such as at school and at home, where such children are likely to be processing and integrating IPS-based social cues differently, potentially contributing to differences in the way they experience and understand social situations. Our findings suggest that children identified as experiencing EB&CDs may benefit from different, more explicit information about social partners. Importantly, our findings demonstrate one way in which differences in social processing may exist in children with high levels of neurodivergent traits but *without* a neurodevelopmental diagnosis, and highlight that such children may require different or additional support as a result. However, support opportunities often depend on a having a formal diagnosis, and even those who eventually go on to receive a diagnosis may experience a long wait time for assessment (Rutherford et al., 2016). Thus, it is important to understand the development of children with functional difficulties but without a formal diagnosis – the so-called 'missing middle' – so that they can receive better-informed early intervention strategies before clinically significant difficulties emerge (National Assembly for Wales Children Young People and Education Committee, 2018, 2020).

Second, although we measured social sensitivity to IPS when perceiving the interactions of others, it may be that IPS has similarly reduced social significance for children with high levels of neurodivergent traits when they take part in interactions directly. Future research should explore the extent to which neurodivergent children are sensitive to IPS in interactions in which they are active participants.

Further, while IPS has been characterised as a 'social glue' (Lakin et al., 2003; Vicaria & Dickens, 2016) in neurotypical populations, this may not be the case for children with high levels of neurodivergent traits and other parent-reported differences. If IPS is of limited social significance for these children, IPS may be less likely to enhance bonding with their social partners. This has clear implications for interventions that seek to increase levels of IPS displayed by neurodivergent people, as a means of enhancing their social skills (e.g. Daniel et al., 2022; Landa et al., 2011; Srinivasan et al., 2015; Yoo & Kim, 2018). Even if such interventions are effective at increasing levels of IPS, they may be much less effective at increasing the extent to which intervention recipients subsequently feel bonded to others. Lastly, the limited relevance of IPS to affiliation in children identified as experiencing EB&CDs underscores the need to identify mechanisms that *do* promote the formation of social bonds in children with high levels of neurodivergent traits, and for a better understanding of neurodivergent patterns of social relating in general (Crompton et al., 2020; Heasman & Gillespie, 2019).

Conclusion

This was the first study to investigate the social effects of IPS in children with EB&CDs. Our findings suggest that IPS is not a robust social cue for children identified as experiencing EB&CDs in the way that it is for neurotypical children. These findings further our understanding of how IPS is experienced differently by children with high levels of neurodivergent traits and other parent-reported differences: not only do they synchronise less than neurotypical peers but,

our current findings suggest, they may also experience IPS as less socially relevant. The range of factors that may explain variation in social sensitivity to IPS remain unclear. However, gender played a significant role in our sample, with girls and boys sensitive to different temporal effects. The current study found no evidence of a dimensional association between sensitivity to IPS and levels of emotional and behavioural difficulties or autistic/ADHD traits. An approach that targets specific underlying processes (e.g. perceptual, motor and social abilities) may shed more light on variation in children's social sensitivity to IPS.

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ORCID iDs

Elisabeth von dem Hagen https://orcid.org/0000-0003-1056-8196

Catherine RG Jones https://orcid.org/0000-0003-0541-0431

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Supplemental Material

Supplemental material for this article is available online.

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