Longitudinal assessment of social cognition in infants born preterm using eye-tracking and parent–child play

Bethan Dean | Sinéad O’Carroll | Lorna Ginnell | Victoria Ledsham | Emma Telford | Sarah Sparrow | James P. Boardman | Sue Fletcher-Watson

1MRC Centre for Reproductive Health, The University of Edinburgh, Edinburgh BioQuarter, Edinburgh, UK
2Centre for Clinical Brain Sciences, The University of Edinburgh, Chancellor’s Building, Edinburgh BioQuarter, Edinburgh, UK
3Salvesen Mindroom Research Centre, The University of Edinburgh, Kennedy Tower, Royal Edinburgh Hospital, Edinburgh, UK

Correspondence
Sue Fletcher-Watson, Salvesen Mindroom Research Centre, The University of Edinburgh, Kennedy Tower, Royal Edinburgh Hospital, Morningside Park, Edinburgh, EH10 5HF, UK.
Email: sue.fletcher-watson@ed.ac.uk

Funding information
Medical Research Council, Grant/Award Number: G1002033; Theirworld

Abstract
Preterm birth is associated with reduced social attention in infancy. Are these early social attention differences linked to later interactive ability? This study draws on a well-characterized preterm cohort in whom we have previously demonstrated a reduced attentional preference for social information in infancy, using eye-tracking. States of engagement during parent–child play at 60 months were coded for 36 preterm- and 31 term-born children. We also repeated the eye-tracking assessment of social attention previously performed in infancy and evaluated neurodevelopment via the Mullen Scales of Early Learning. Children born preterm or at term spent similar percentages of time in different engagement states. Infant and child social attentional profiles did not relate to the complexity of engagement. Preterm infants’ language impairments correlated with time spent in conversational joint engagement. Children born preterm showed complex social interaction abilities unrelated to their profile of social attention in infancy.

KEYWORDS
development, eye gaze, parent–child play, prematurity, social cognition

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2021 The Authors. Infant and Child Development published by John Wiley & Sons Ltd.
1 | BACKGROUND

Preterm birth, defined as birth before 37 completed weeks of gestation, affects 10.6% of births globally (Chawanpaiboon et al., 2019) and is associated with neurocognitive, language and social impairment in children (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Johnson & Marlow, 2017). Impairments in the social domain not only cause difficulties in educational performance and peer relationships in childhood, but detrimentally affect social and occupational functioning in adulthood (Woodward & Fergusson, 1999, 2000). Preterm birth is also associated with higher diagnostic rates of autism (Johnson et al., 2009), a condition defined in part by distinctive social features (American Psychiatric Association, 2013; World Health Organization, 2019). However, some have suggested that the specific social cognitive and interactive profile of preterm infants may be overlapping with, but distinct from autism (Arpi & Ferrari, 2013; Johnson & Marlow, 2011; Montagna & Nosarti, 2016). Social difficulties are often not apparent during early years, during which routine NHS preterm follow-up occurs, as most social interactions are relatively simple and take place primarily on a one-to-one basis. Subsequently, difficulties are often not picked up until the child enters school, when the social expectations of peers and adults increase in complexity. In addition, social difficulties appear in only a sub-set of children born early (Chapieski & Evankovich, 1997; Ritchie, Bora, & Woodward, 2015; Zmyj, Witt, Weitkamper, Neumann, & Lucke, 2017), and while gestational age at birth relates generally to outcome (Kerr-Wilson, Mackay, Smith, & Pell, 2011; MacKay, Smith, Dobbie, & Pell, 2010; Moore et al., 2012), there is no specific predictor of which children will or will not experience problems in the social domain. This context poses two major challenges to improving long-term outcomes for preterm infants. One is early identification of those who will have social difficulties, with a view to providing targeted early intervention during the potential “missed years” between NHS follow-up and starting school. The other is mapping the social cognitive and interactional profile of children born preterm in sufficient detail to be able to examine degree of overlap with autism.

One attempted solution to both of these challenges is the use of gaze measures to detect early signs of social differences in preverbal infants. Gaze studies in preterm infants have shown consistent patterns of reduced attentional preference to social information (citation removed for blind peer review, Frie, Padilla, Aden, Lagercrantz, & Bartocci, 2016; Imafuku et al., 2017; Pereira et al., 2017; Telford et al., 2016). Eye-tracking measures of gaze to social information have been successful, to some degree, in predicting diagnostic outcome for children who later receive a diagnosis of autism (Chawarska, Macari, & Shic, 2013; Jones, Carr, & Klin, 2008) although this mapping is not always precise (Elsabbagh et al., 2013). Thus, eye-tracking may have potential to stratify preterm infants according to their social profile, enabling clinicians to make predictions about later social outcome and provide targeted support. It could also help us to chart the relations between autism and prematurity. However, the predictive value of eye-tracking and indeed the general stability of early attentional preferences, and their relations to ecologically valid measures of child behaviour, is yet to be established in the preterm population.

This study draws on a well-characterized preterm cohort in whom we have previously demonstrated a reduced social attentional preference in infancy, measured across multiple eye-tracking tasks that have been previously used.
in both infant (citation removed for blind peer review) and adult populations (citation removed for blind peer review) to capture differences between clinical groups at different ages (citation removed for blind peer review). At 5 years of age, the preterm group demonstrated an equivalent social attentional pattern to their term-born peers, suggesting an apparent developmental catch-up (citation removed for blind peer review). However, the preterm group still showed lower scores on standardized neurodevelopmental assessments at 5 years, mainly driven by language difficulties. One interpretation of this finding is that reduced social attention during an early sensitive window (Meredith, 2015) may result in deficits in more complex, downstream social interactive abilities, even if the attentional difference itself is no longer detectable. Therefore, it is also important to establish whether this preterm group shows real-world social interactive difficulties, beyond what we can measure with an eye-tracker.

To deliver greater ecological validity, in order to answer this question, we aimed at capturing a naturalistic interaction and extracting quantitative measures of pivotal behaviours that have demonstrable predictive value in social cognitive development. Such pivotal behaviours include coordinated attention (Charman, 2003; Morales et al., 2000; Mundy & Newell, 2007; Nelson, Adamson, & Bakeman, 2008; Sheinkopf, Mundy, Claussen, & Willoughby, 2004), symbolic play (Adamson, Bakeman, & Deckner, 2004; Adamson, Bakeman, Deckner, & Nelson, 2014; Bornstein & Tamis-LeMonda, 1995) and conversation (Adamson et al., 2004, 2014; Adamson & Bakeman, 2006). We recorded a parent–child interaction in a play setting and evaluated this using a modified coding scheme capturing joint engagement (Bakeman & Adamson, 1984). The selected scheme measures engagement between the child and parent, the child’s attentional focus, and the use of symbolic play and conversation to scaffold the interaction.

We hypothesized that we would detect social cognitive differences in the preterm group during parent–child play, with a smaller proportion of time spent in more complex engagement states compared with children born at term. We also hypothesized an association between smaller social attentional preference scores from eye-tracking tasks and less time spent in more complex joint engagement states during parent–child play (a) cross-sectionally at 5 years and (b) longitudinally (from infancy to 5 years). Finally, we planned an exploratory analysis into the relation between measures derived from our behavioural analysis of parent–child play and those from standardized tests of neurodevelopment, to allow us to place any differences seen in a broader developmental context.

2 | MATERIALS AND METHODS

2.1 | Participants

A cohort of 50 preterm infants (gestational age < 33 + 0 weeks) and 50 healthy term control infants (gestational age ≥ 37 + 0 weeks), recruited in infancy as previously reported (citation removed for blind peer review), were recalled at 5 years of age. The infants were originally recruited between 2013 and 2015 from the removed for blind peer review NICU, postnatal wards, and from community groups. Exclusion criteria were major congenital malformations, congenital infections and major overt parenchymal lesions. Families were recontacted again at 5 years of age, initially by letter, with subsequent telephone contact. Corrected age was used in infancy, and chronological age at 5 years, as per standard practice regarding developmental assessment of preterm infants (Johnson & Marlow, 2006). We obtained ethical approval from removed for blind peer review for all participants originally recruited from hospital services and from removed for blind peer review for term infants recruited from the community. Informed written parental consent was obtained. Deprivation was reported using the Scottish Index of Multiple Deprivation 2016 (SIMD-2016), a government tool that uses multiple measures to assign a level of deprivation to a small area called a data zone, which are then ranked from most (1) to least (6976) deprived (Scottish Government, 2016), and reported in quintiles.
2.2 | Parent–child play procedure

The parent–child play took place in a specialist child-friendly laboratory in the university. We provided a standard set of age-appropriate toys and left the parent and child to play together for 10 min with the instructions to ‘play as you would do at home.’ Toys were selected to provide opportunities for a range of play types, including construction (e.g., Duplo blocks), cause-and-effect (e.g., glockenspiel) and symbolic (e.g., tea set, figurines). The toys were laid out on a $1.1 \times 1.1$ m playmat, and the parent and child asked to remain on the mat during play, in order to stay on camera. We video-recorded the play using a Panasonic HC-W580 camera positioned in the corner of the room and coded the videos retrospectively using ELAN software (ELAN., 2017; Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006).

2.3 | Coding scheme

The parent–child play was coded using the Bakeman and Adamson states of engagement scheme (Bakeman & Adamson, 1984), with extensions developed specifically for this study. The scheme was chosen because it captures engagement during play, be it shared with the parent, or in instances of no interaction, where instead the child’s attention is directed. The original scheme classifies the child’s activity into six mutually exclusive and exhaustive states of engagement: unengaged, on-looking, person engagement, object engagement and joint engagement (passive and coordinated). It is well validated in typically developing children as well as those with autism and Down syndrome, with longitudinal studies documenting relations between engagement states and later cognitive and communicative abilities (Adamson, Bakeman, Deckner, & Romski, 2008; Bakeman & Adamson, 1984; Kaale, Smith, Nordahl-Hansen, Fagerland, & Kasari, 2018; Nelson et al., 2008). However, the published literature on the original scheme’s use in this age group of children is restricted to populations with neurodevelopmental disorders, in particular those with language delay (Kaale, Fagerland, Martinsen, & Smith, 2014; Kaale, Smith, & Sponheim, 2012; Lewy & Dawson, 1992; Nordahl-Hansen, Fletcher-Watson, McConachie, & Kaale, 2016; Wong & Kasari, 2012). This raises the risk of ceiling effects and, consequently, lowers sensitivity to detect effects at the higher levels of engagement in the study population. We therefore adapted the scheme to our age group as follows. First, we expanded the definitions of the existing engagement states to accommodate the increased use of language by the child. Second, we added three additional engagement state codes as sub-sets of coordinated joint engagement, designed to capture more sophisticated levels of social cognitive behaviour in interaction. Therefore, our final coding scheme consisted of nine states, as detailed in Table 1. Full description of the coding scheme and rules can be found in supplementary material (Data S1).

The author coded all videos, with a 15% sample double-coded for intra-rater reliability, and a second 15% sample coded by the second author for inter-rater reliability. The author was not blinded to the group, as she performed the appointment and parents often disclosed the child’s history, but the second coder was blinded to the group, and the parents and children blinded to the purpose of the study. We assessed reliability using Cohen’s kappas (Cohen, 1960), to assess the reliability of the scale while correcting for chance agreement (Bakeman & Quera, 2011), computed on a second-by-second basis. A tolerance window was permitted, with agreement counted if the second observer coded the same state within 2 s of the first observer. Kappas were calculated using GSEQ software (Bakeman, 2011). Mean kappas assessing intra- and inter-rater reliability were 0.90 and 0.95, respectively, for time, and 0.82 and 0.87, respectively, for events, which are values that Fleiss, Levin, and Paik (2013) designated excellent.

2.4 | Eye-tracking procedure

The children were presented with three free-viewing social tasks, identical to those administered in infancy (citation removed for blind peer review). Full details of the eye-tracking procedure are reported elsewhere (citation removed
In summary, in three tasks that presented stimuli of increasing social complexity, the social content focused on the eye region of a face, a human image in an array of non-human images and the presence of humans within a naturalistic scene. For each task, we predetermined a socially informative area of interest and calculated a proportional looking score to this social area of interest, across all stimuli within that task, as the ratio of the mean looking time to the whole scene. For each individual, an overall social preference score was calculated from the average of the proportional looking scores for each task. In this article, we use the proportional looking scores to social areas of interest per task and the overall social preference score across the three tasks, which have previously been established as reliable and valid.

### Developmental assessment

All children were assessed using the Mullen Scales of Early Learning (MSEL) (Mullen, 1995). Data are reported in and analysed using the domain t-scores and the Early Learning Composite score (Johnson & Marlow, 2006).

### Analysis methods

We compared group demographics using independent-sample t, Mann–Whitney U or chi-square tests as appropriate for normally distributed, rank or binomial data, respectively. We also compared the demographics of the children seen at 5 years and those lost to follow-up.

For parent–child play data, the ELAN output was exported to Microsoft Excel including start time and duration of each engagement state. We calculated summary scores for the percentage of time spent in each engagement state, as well as two composite categories of all coordinated joint engagement states (6 + 6a–c) and all higher-order

| TABLE 1 States of engagement coding scheme |
|------------------------------------------|
| Engagement state | Description |
|------------------|-------------|
| 1. Unengaged     | Child appears to be uninvolved with any specific person, object or event. |
| 2. On-looking    | Child is observing parent's activity. Child may be looking attentively but is not otherwise participating in any way. |
| 3. Person engagement | Child is interacting with parent with no object at hand. |
| 4. Object engagement | Child is just attending to an object or event that the parent is not involved in. |
| 5. Supported joint engagement | Child and parent are busy with the same game/object/event, but child shows no clear confirmation of parent's participation. |
| 6. Coordinated joint engagement | Child and parent are actively involved with the same game/object/event. Child clearly and repeatedly acknowledges parent's participation. Child coordinates their attention to both parent and the game/object/event they share. |
| 6a. Symbolic joint engagement | Child and parent are jointly engaged with something not visible/present. Child bids to engage parent to share their imagination with sufficient information to allow shared understanding. If initiated by parent, child shows sufficient evidence of independent understanding of symbolism. |
| 6b. Conversational joint engagement | Child and parent are jointly engaged in talk which coherently flows to and from each other with both building on the information from the other and allowing a response. Needs to include at least one child–parent–child sequence. |
| 6c. Child-led joint engagement | Child in charge, directing the interaction and skilfully working to engage the parent (independent of the parent's response—Looking to credit the child not parent). |
coordinated joint engagement stated (6a–c). Percentages were calculated from the total time spent in that state, divided by the total coded time (excluding time off camera). This allowed direct comparability across all participants, even if the full 10 min was not coded.

The eye-tracking data were processed as detailed in (citation removed for blind peer review). For these analyses, we used the proportional looking scores and social preference score only. The domain t-scores and Early Learning Composite score were used from the MSEL.

We assessed normality using Shapiro–Wilk’s test of normality (p > .05) and visual inspection of histograms and QQ plots. For normally distributed data, we report mean and standard deviation and used the independent-sample t test for group comparisons. Where data did not meet the normality assumption, we report median, inter-quartile range and used the Mann–Whitney U test. Correlations were examined using Spearman’s rank correlations. SPSS version 22 (SPSS Inc., 2013) was used for the statistical analysis. Two-tailed p values are reported, and p < .05 was considered statistically significant.

3 | RESULTS

3.1 | Participant characteristics

Thirty-six preterm and 31 term infants were seen at 5 years of age (Table 2), all of whom had been previously seen in infancy. The groups were significantly different in gestational age and birthweight, as would be expected, but also differed significantly in SIMD-2016 rank and age at 5-year assessment; the term group were of higher socio-economic status and slightly older on average at the 5 year recall. There were no significant differences in birthweight, gestational age, gender or SIMD-2016 between those that attended at 5 years and those who were lost to follow-up.

3.2 | Coding metrics

Sixty-two (93%) children provided a codable parent–child play sample. Five videos (three preterm, two term) were unable to be coded: four due to the parent and child not speaking in English and one due to technical error. Ten minutes of play was coded in 90% of videos, but six children (three preterm, three term) did not have a full 10 min (range: 9 min 20 s to 9 min 50 s) due to time spent off camera or insufficient video available. The parent was the mother in 56 videos and the father in six, all from the preterm group.

| TABLE 2 | Demographic characteristics of participants |
|----------------|-----------------------------------------------|
| Characteristic          | Preterm (n = 36) | Term (n = 31) | p value |
| Mean (range) gestational age at birth/weeks | 29±2 (23–33) | 40±1 (37–42) | <.005 |
| Mean (SD) birthweight/grams | 1121 (244) | 3613 (400) | <.005 |
| Median (IQR) age testing as infant/months<br>a | 7.3 (6.5–8.7) | 8.0 (7.3–9.3) | .191 |
| Median (IQR) age testing as child/months | 60.2 (59.9–60.8) | 64.2 (60.7–67.0) | .001 |
| Gender (M:F) | 18:18 | 16:15 | .895 |
| Median (IQR) SIMD-2016 rank | 2793 (2027–5146) | 5,577 (4736–6480) | .001 |
| % of sample by SIMD-2016 quintile | 1:11% <br>2–4:69% <br>5:20% | 1:0% <br>2–4:53% <br>5:47% |

Note: Normally distributed data reported as M (SD), non-normally distributed data reported as median (inter-quartile range). The bold values are indicate the P < 0.05.

Abbreviations: IQR, inter-quartile range; SIMD-2016, Scottish Index of Multiple Deprivation 2016.

aValues for preterm group corrected for gestational age at birth.
3.3 Group differences in engagement states during parent–child play

The percentage of time spent in any one state during parent–child play and the composite categories can be seen in Table 3. Few children spent a small proportion of time unengaged \((n = 7, < 2.2\%)\), on-looking \((n = 2, < 2.7\%\) or in person \((n = 6, < 6.7\%\) engagement states, and therefore, these states were collapsed together for subsequent analyses. All children spent the majority of the play \((\text{median} > 90\% \text{ in both groups})\) in coordinated joint engagement \((\text{Table 3 and Figure 1})\). There were no significant group differences between the percentages of time spent in any one state during the

| Engagement state                  | Preterm \((n = 33)\) | Term \((n = 29)\) | Median difference | \(p\) value | Effect size \(a\) |
|----------------------------------|-----------------------|-------------------|-------------------|-------------|-------------------|
| Unengaged/on-looking/person      | 0.00 (0.00–0.00)      | 0.00 (0.00–0.78)  | 0.00              | .08         | −0.22             |
| Object                           | 6.52 (1.63–11.57)     | 5.35 (2.85–15.82) | 1.17              | .557        | −0.07             |
| Supported joint                  | 0.00 (0.00–0.70)      | 0.00 (0.00–2.11)  | 0.00              | .320        | −0.13             |
| Coordinated joint                | 44.36 (24.61–58.19)   | 42.84 (29.39–59.07)| 1.52             | .751        | −0.04             |
| Symbolic joint                   | 26.29 (15.06–42.95)   | 20.27 (10.42–35.93) | 6.02              | .306        | 0.13              |
| Conversational joint             | 3.97 (0.00–10.23)     | 7.32 (3.41–10.46) | −3.34            | .102        | −0.21             |
| Child-led                        | 10.49 (4.50–19.17)    | 9.67 (2.72–17.90) | 0.81              | .326        | 0.12              |
| All combined coordinated joint   | 91.86 (85.57–97.84)   | 90.93 (81.79–95.16) | 0.93             | .256        | 0.14              |
| All higher-order coordinated joint| 49.30 (31.16–68.36)  | 38.86 (27.16–59.62) | 10.45            | .256        | 0.14              |

Note: Normally distributed data reported as \(M (SD)\), non-normally distributed data as median (inter-quartile range).

\(a\) Preterm compared to term.
parent–child play (Table 3, Figure 2; all Cohen’s $d \leq 0.22$). There were also no significant group differences for the composite categories of all coordinated or all higher-order coordinated states of engagement (Figure 1; Cohen’s $d = 0.14$).

Because of the increased representation of lower socio-economic backgrounds and higher age at recall in our preterm group, we ran correlations to explore whether either factor could be a confounder. There was no significant correlation between SIMD-2016 rank or chronological age and time spent in any of the coordinated states of engagement, including the composite categories. Due to a lack of significant group differences between the preterm and term infants, the groups were combined for further analyses. A post-hoc power calculation revealed that this sample yields 92% power to detect correlation effect sizes that are moderate ($|p| = .4$) or above (Faul, Erdfelder, Buchner, & Lang, 2009).

3.4 | Association between engagement states in parent–child play and eye-tracking measures

There were no significant correlations cross-sectionally between the eye-tracking task-specific proportional looking scores, or overall social preference score, at 5 years with percentage of time spent in any of the coordinated joint engagement states, including the composite categories, during parent–child play. There were also no significant longitudinal correlations seen between eye-tracking scores in infancy and percentage of time spent in any of the coordinated engagement states, including the composite categories, during parent–child play at 5 years of age.

3.5 | Association between engagement states in parent–child play and neurodevelopment

The MSEL scores at 5 years are reported in Table 4. There were significant group differences in Early Learning Composite score with preterm children scoring lower than term children (95 vs. 104, $p = .025$), mainly due to language impairments. Time spent in conversational joint engagement correlated with expressive language $t$ score in the MSEL.
Reviewing the parent–child play data, it can be seen that preterm children spent a lower median percentage of time in conversational joint engagement than their term-born peers, but this did not meet statistical significance (3.97 vs. 7.32, $U = 363$, $z = -1.64$, $p = .102$, Cohen's $d = 0.21$).

### DISCUSSION

In our sample, preterm infants show equivalent social cognitive development at 5 years of age to children born at term, as measured by observational coding of engagement state during parent–child play. Cross-sectionally, we found no evidence of individual differences whereby children’s engagement states related to their social attentional preference collected at the same appointment. Longitudinally, we found no evidence of a link between eye-tracking measures of social attentional preference in infancy and reduced complexity of social interaction at 5 years. This is despite the fact that the study was well-powered to detect moderate and large effect sizes.

We do not suspect that our null result is due to failure in the coding scheme to identify children with social difficulties, as it was chosen precisely for this outcome. Studies using the original scheme show that time in coordinated joint engagement relates to social cognitive outcome measures (Nelson et al., 2008) and was reduced in children with autism (Adamson et al., 2008). The median proportion of time spent in a coordinated state of joint engagement was over 90% in both groups, supporting our decision to extend the scheme to avoid a ceiling effect. In addition, we found a significant correlation between time spent in conversational joint engagement during parent–child play and expressive language domain t-score on the MSEL, supporting the validity of the extended scheme. Likewise, our eye-tracking data derives from tasks and scores that have previously been validated in infancy (citation removed for blind peer review) with group differences that persisted when extended to a larger cohort (citation removed for blind peer review) and are consistent with other studies of visual social attention in the first year of life (Frie et al., 2016; Imafuku et al., 2017; Pereira et al., 2017).

An alternative explanation is that, although relative risk of social difficulties is increased in preterm birth, and we had power to detect moderate effects, the sample size could lead to type II error if the true effect size is small. Although our scheme was designed to assess the child as independently as possible, there remains risk that parental factors and behaviour confound our ability to detect child-centred differences. In particular, parental scaffolding may mask subtle difficulties and these may become more apparent during observation of interactions with peers rather than a parent.

In addition, a systematic review of studies of social cognition in children born preterm has highlighted heterogeneity in methods used to study social cognition and the subsequent challenges of integrating these results to better understand social cognitive development (citation removed for blind peer review). Indeed, there remains many unknowns about social cognition as a construct itself, and while a construct is imprecisely defined, it is almost impossible to identify a standard assessment applicable from infancy to early childhood. It is feasible that the null result reflects measurement of different underlying constructs between eye-tracking and parent–child play tasks.

### TABLE 4  Mullen scale of early learning at 5 years

|                      | Preterm ($n = 34$) | Term ($n = 28$) | $p$ value |
|----------------------|--------------------|----------------|-----------|
| Visual reception     | 47 (10.45)         | 53 (47–57)     | .113      |
| Fine motor           | 44 (10.46)         | 48 (8.05)      | .168      |
| Receptive language   | 47 (9.07)          | 54 (51–60)     | .004      |
| Expressive language  | 49 (10.57)         | 54 (5.40)      | .030      |
| Early learning composite | 95 (16.35)    | 104 (10.75)    | .025      |

Note: Normally distributed data reported as $M$ (SD), non-normally distributed data as median (inter-quartile range). The bold values are indicate the $P < 0.05$. 

$r_{53} = .30, p = .031$. Reviewing the parent–child play data, it can be seen that preterm children spent a lower median percentage of time in conversational joint engagement than their term-born peers, but this did not meet statistical significance (3.97 vs. 7.32, $U = 363$, $z = -1.64$, $p = .102$, Cohen's $d = 0.21$).
For example, the early social attentional differences seen in eye-tracking tasks could be explained by more domain-general skills such as attentional control, rather than social preference.

Nonetheless, how can we interpret our null result if it was true? The simplest explanation is that infants born preterm display early differences in social cognition, but by age five have shown developmental catch-up, both in laboratory-based and more ecologically valid, behavioural measures. In partial support of this, previous studies that have shown significant differences in interactive behaviours of preterm infants during play tend to be at a younger age (Landry, Denson, & Swank, 1997; Landry, Smith, Miller-Loncar, & Swank, 1998). Our data, while longitudinal, capture only two time points more than 4 years apart, meaning we are not able to more closely describe the trajectories of social development in infants born preterm. Differences in social interaction may also be driven by other important factors that overlap with prematurity such as socio-economic status (Fuertes, Faria, Soares, & Crittenden, 2009; Landry, Denson, & Swank, 1997; Landry, Smith, Miller-Loncar, & Swank, 1997), maternal education (Fuertes et al., 2009) and maternal mental health (Neri, Agostini, Salvatori, Biasini, & Monti, 2015), with equivalence to term-born infants seen at a similar age to our cohort (Kirsh, Cnric, & Greenberg, 1995; Landry, Smith, Swank, & Miller-Loncar, 2000). We found no significant relation with socio-economic deprivation in this study, but we did not explore associations with maternal education or mental health.

Moving forwards, the early identification of the sub-set of preterm infants that go on to have social difficulties remains a challenge. Our data do not indicate great stability in social cognition, measured first via attentional preference and later via attention and interaction, in this sample. Early social attentional differences have been consistently found in children born preterm, but better definition of the trajectory of these differences, using multiple time points in childhood, is needed. Further contemplation of the most relevant, ecologically valid assessments of social cognition is also required, with consideration of use of peer-to-peer interaction, to remove potential masking of subtle differences by parental scaffolding. Finally, cross-sectional comparison of assessments of social cognition in different contexts, such as the lab and more ecologically valid environments, is needed to ensure measurement of the same underlying construct. This would aid in the verification of a single underlying developmental pathway for the social domain, as well as revealing its role in the ontogeny of the social difficulties seen in the preterm population.

5 | CONCLUSION

A cohort of children born preterm previously shown to have reduced social attentional preference in infancy have shown equivalent social cognitive development at 5 years of age to term-born children, when measured using both a laboratory-based eye-tracking measure and an ecologically valid behavioural measure. Early identification of the sub-set of preterm infants that go on to develop social difficulties remains a challenge. Future research should examine the role of atypical infant social attentional preference in the development of interactive abilities generally, in order to define the optimal method for modelling the social problems experienced by children born preterm.

ACKNOWLEDGEMENTS

We are grateful to all families who consented to take part in the study. The study was funded by Theirworld (http://www.theirworld.org) and was carried out in the MRC Centre for Reproductive Health (MRC G1002033).

CONFLICT OF INTEREST

The authors declare they have no competing or potential conflicts of interest.

AUTHOR CONTRIBUTIONS

Bethan Dean: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; visualization; writing–original draft; writing–review and editing. Sinead O’Carroll: Investigation. Lorna Ginnell: Investigation; project administration. Victoria Ledsham: Investigation; project administration. Emma Telford: Investigation; project administration. Sarah Sparrow: Investigation; project administration. James Boardman: Conceptualization;
funding acquisition; supervision; writing–review and editing. Sue Fletcher-Watson: Conceptualization; funding acquisition; supervision; writing–review and editing.

ETHICS APPROVAL AND PATIENT CONSENT STATEMENT
Ethical approval was obtained from National Research Ethics Service (South East Scotland Research Ethics Committee 01) for all participants originally recruited from hospital services, and from the University of Edinburgh School of Philosophy, Psychology and Language Sciences Research Ethics Committee for term infants recruited from the community. Informed written parental consent was obtained.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request due to privacy/ethical restrictions.

ORCID
Bethan Dean [https://orcid.org/0000-0003-3959-0899]
Sue Fletcher-Watson [https://orcid.org/0000-0003-2688-1734]

REFERENCES
Adamson, L. B., & Bakeman, R. (2006). Development of displaced speech in early mother-child conversations. Child Development, 77(1), 186–200. https://doi.org/10.1111/j.1467-8624.2006.00864.x
Adamson, L. B., Bakeman, R., & Deckner, D. F. (2004). The development of symbol-infused joint engagement. Child Development, 75(4), 1171–1187. https://doi.org/10.1111/j.1467-8624.2004.00732.x
Adamson, L. B., Bakeman, R., Deckner, D. F., & Nelson, P. B. (2014). From interactions to conversations: The development of joint engagement during early childhood. Child Development, 85(3), 941–955. https://doi.org/10.1111/cdev.12189
Adamson, L. B., Bakeman, R., Deckner, D. F., & Romski, M. (2008). Joint engagement and the emergence of language in children with autism and Down syndrome. Journal of Autism and Developmental Disorders, 39(1), 84–96. https://doi.org/10.1007/s10803-008-0601-7
American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). Washington, DC: American Psychiatric Association.
Arpi, E., & Ferrari, F. (2013). Preterm birth and behaviour problems in infants and preschool-age children: A review of the recent literature. Developmental Medicine & Child Neurology, 55(9), 788–796. https://doi.org/10.1111/dmcn.12142
Bakeman, R. (2011). GSEQ (Version 5.1). Retrieved from http://bakeman.gsucreate.org/downloads/
Bakeman, R., & Adamson, L. B. (1984). Coordinating attention to people and objects in mother-infant and peer-infant interaction. Child Development, 55(4), 1278–1289.
Bakeman, R., & Quera, V. (2011). Sequential analysis and observational methods for the behavioral sciences. Cambridge, UK: Cambridge University Press.
Bhutta, A. T., Cleves, M. A., Casey, P. H., Cradock, M. M., & Anand, K. J. (2002). Cognitive and behavioral outcomes of school-aged children who were born preterm: A meta-analysis. JAMA, 288(6), 728–737.
Bornstein, M. H., & Tamis-LeMonda, C. S. (1995). Parent-child symbolic pay: Three theories in search of an effect. Developmental Review, 15(4), 382–400. https://doi.org/10.1006/drev.1995.1015
Chapleski, M. L., & Evanovich, K. D. (1997). Behavioral effects of prematurity. Seminars in Perinatology, 21(3), 221–239.
Charman, T. (2003). Why is joint attention a pivotal skill in autism? Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences, 358(1430), 315–324. https://doi.org/10.1098/rstb.2002.1199
Chawanpaiboon, S., Vogel, J. P., Moller, A. B., Lumbiganon, P., Petzold, M., Hogan, D., ... Gulmezoglu, A. M. (2019). Global, regional, and national estimates of levels of preterm birth in 2014: A systematic review and modelling analysis. Lancet Global Health, 7(1), e37–e46. https://doi.org/10.1016/s2214-109x(18)30451-0
Chawarska, K., Macari, S., & Shic, F. (2013). Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism Spectrum disorders. Biological Psychiatry, 74(3), 195–203. https://doi.org/10.1016/j.biopsych.2012.11.022
Cohen, J. (1960). A coefficient of agreement for nominal scales. Educational and Psychological Measurement, 20(1), 37–46. https://doi.org/10.1177/00131644600200104
ELAN (Version 5.0.0-beta) [Computer software]. (2017). Nijmegen: Max Planck Institute for Psycholinguistics. Retrieved from https://tla.mpi.nl/tools/tla-tools/elan/
Montagna, A., & Nosarti, C. (2016). Socio-emotional development following very preterm birth: Pathways to psychopathology. *Frontiers in Psychology, 7*, 80–80. https://doi.org/10.3389/fpsyg.2016.00080

Moore, T., Hennessy, E. M., Myles, J., Johnson, S. J., Draper, E. S., Costeloe, K. L., & Marlow, N. (2012). Neurological and developmental outcome in extremely preterm children born in England in 1995 and 2006: The EPICure studies. *British Medical Journal, 345*, e7961. https://doi.org/10.1136/bmj.e7961

Morales, M., Mundy, P., Delgado, C. E. F., Yale, M., Messinger, D., Neal, R., & Schwartz, H. K. (2000). Responding to joint attention across the 6–through 24-month age period and early language acquisition. *Journal of Applied Developmental Psychology, 21*(3), 283–298. https://doi.org/10.1016/S0193-3973(99)200040-4

Mullen, E. M. (1995). *Mullen scales of early learning manual: AGS Edition*. Circle Pines, MN: American Guidance Service.

Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. *Current Directions in Psychological Science, 16*(5), 269–274. https://doi.org/10.1111/j.1467-8721.2007.00518.x

Neri, E., Agostini, F., Salvatori, P., Biasini, A., & Monti, F. (2015). Mother-preterm infant interactions at 3 months of corrected age: Influence of maternal depression, anxiety and neonatal birth weight. *Frontiers in Psychology, 6*, 1234. https://doi.org/10.3389/fpsyg.2015.01234

Nordahl-Hansen, A., Fletcher-Watson, S., McConachie, H., & Kaale, A. (2016). Relations between specific and global outcome measures in a social-communication intervention for children with autism spectrum disorder. *Research in Autism Spectrum Disorders, 29–30*, 19–29. https://doi.org/10.1016/j.rasd.2016.05.005

Pereira, S. A., Pereira Junior, A., Costa, M. F., Monteiro, M. V., Almeida, V. A., Fonseca Filho, G. G., ... Simion, F. (2017). A comparison between preterm and full-term infants' preference for faces. *Journal de Pediatria, 93*(1), 35–39. https://doi.org/10.1016/j.jped.2016.04.009

Ritchie, K., Bora, S., & Woodward, L. J. (2015). Social development of children born very preterm: A systematic review. *Developmental Medicine & Child Neurology, 57*(10), 899–918. https://doi.org/10.1111/dmnc.12783

Scottish Government. (2016). *Scottish Index of Multiple Deprivation*. Retrieved from http://www.gov.scot/Topics/Statistics/SIMD

Sheinkopf, S. J., Mundy, P., Claussen, A. H., & Willoughby, J. (2004). Infant joint attention skill and preschool behavioral outcomes in at-risk children. *Development and Psychopathology, 16*(2), 273–291. https://doi.org/10.1017/S09545794044517

SPSS Inc. (2013). *IBM SPSS statistics for windows (version 22.0)*. Armonk, NY: IBM Corp.

Telford, E. J., Fletcher-Watson, S., Gillespie-Smith, K., Pataky, R., Sparrow, S., Murray, I. C., ... Boardman, J. P. (2016). Preterm birth is associated with atypical social orienting in infancy detected using eye tracking. *Journal of Child Psychology and Psychiatry, 57*(7), 861–868. https://doi.org/10.1111/jcpp.12546

Wittenburg, P., Brugman, H., Russel, A., Klassmann, A., & Sloetjes, H. (2006). ELAN: A professional framework for multimodality research. Paper presented at the Proceedings of the 5th international conference on language resources and evaluation(LREC 2006),1556–1559.

Wong, C., & Kasari, C. (2012). Play and joint attention of children with autism in the preschool special education classroom. *Journal of Autism and Developmental Disorders, 42*(10), 2152–2161. https://doi.org/10.1007/s10803-012-1467-2

Woodward, L. J., & Fergusson, D. M. (1999). Childhood peer relationship problems and psychosocial adjustment in late adolescence. *Journal of Abnormal Child Psychology, 27*(1), 87–104.

Woodward, L. J., & Fergusson, D. M. (2000). Childhood peer relationship problems and later risks of educational underachievement and unemployment. *Journal of Child Psychology and Psychiatry, 41*(2), 191–201.

World Health Organization. (2019). *International statistical classification of diseases and related health problems* (11th ed.). Geneva, Switzerland: World Health Organization.

Zmyj, N., Witt, S., Weitkamper, A., Neumann, H., & Lucke, T. (2017). Social cognition in children born preterm: A perspective on future research directions. *Frontiers in Psychology, 8*, 455. https://doi.org/10.3389/fpsyg.2017.00455

**SUPPORTING INFORMATION**

Additional supporting information may be found in the online version of the article at the publisher's website.