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How 2- and 4-year-old children coordinate social interactions with peers

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The Interaction Engine Hypothesis postulates that humans have a unique ability and motivation for social interaction. A crucial juncture in the ontogeny of the interaction engine could be around 2–4 years of age, but observational studies of children in natural contexts are limited. These data appear critical also for comparison with non-human primates. Here, we report on focal observations on 31 children aged 2- and 4-years old in four preschools (10 h per child). Children interact with a wide range of partners, many infrequently, but with one or two close friends. Four-year olds engage in cooperative social interactions more often than 2-year olds and fight less than 2-year olds. Conversations and playing with objects are the most frequent social interaction types in both age groups. Children engage in social interactions with peers frequently (on average 13 distinct social interactions per hour) and briefly (28 s on average) and shorter than those of great apes in comparable studies. Their social interactions feature entry and exit phases about two-thirds of the time, less frequently than great apes. The results support the Interaction Engine Hypothesis, as young children manifest a remarkable motivation and ability for fast-paced interactions with multiple partners.

This article is part of the theme issue 'Revisiting the human 'interaction engine': comparative approaches to social action coordination'.

1. Introduction

It has long been argued that social interaction is 'the primordial site of human sociality' [1, p. 54] and that contrary to popular belief, one of the most remarkable capacities of human beings is not language, but rather a special propensity to interact with one another, with no equivalent in other animal species, may it be in quantity or quality [2,3]. The claim goes as far as suggesting that language, our ability to cooperate with each other and cultural accumulation are all crucially dependent on what has been called an 'interaction engine' [2,3]. Notably, this 'engine' is not a module in the brain or a single cognitive mechanism, but rather a set of proclivities with different phylogenetic origins and ontogenetic developments that drives the way humans interact with each other and that appear to be fundamentally universal, i.e. a property of the species more than the byproduct of socialization.

Joint activities are the natural home in which the interaction engine displays its strengths [4,5]. When two or more individuals come to coordinate their actions towards achieving a shared goal (that no individual could achieve alone), each individual is faced with the challenge of considering not just how their own action will help achieve their goal, but also of monitoring the actions of their social partners, making predictions about them, coordinating and possibly correcting or adjusting their own conduct. At a very basic level, joint activities require joint attention (knowing what others can and cannot perceive); predicting what others will do, based on their ongoing behaviour but also based on past interactions, knowing what others should do to achieve the common goal [6]. According to some, this requires a matching of plans and subplans [5,7] that on the surface appear to pose major cognitive demands and that some would claim is observable in children only around 5 years of age (e.g. [8]). Yet, although engaging in joint activities might present complex cognitive challenges, the average human engages in joint activities for several hours a day (e.g. through conversation), and children as young as 2-year olds appear to be able to coordinate their actions with others (e.g. [9]). It has thus been argued that coordination to accomplish joint activities might not necessarily rely on complex cognitive abilities but could be achieved through alignment of behaviours, allowing for a comparison to non-human animals social interactions towards investigating its evolutionary origins.

In this paper, we would like to propose a move analogous to the distinction made by [10] between joint commitment as product and as process. Where joint commitment-as-product refers to the feeling of normative obligation to each other and to completing the joint action that participants might experience, while joint commitment-as-process refers to the exchange of signals between participants. In other words, the sense of commitment (the product) emerges from the signal exchange (the process) [11]. To this end, rather than focusing on the cognitive computations necessary to achieve joint actions, we want to broaden our target and focus on the behavioural exchange of signals between young children engaged in social interactions (including interactions in which goals might not be aligned, like in conflicts) to document when and how they appear to behave in a more adult like manner and how they compare to our closest living relatives (chimpanzees and bonobos). From a behavioural point of view, engaging in social interactions usually entails the sequential unfolding of three phases with recognizable communicative signals: (i) an entry phase, (ii) a main body, and (iii) an exit phase [4]. Entry phases represent the process through which a child recruits another towards engaging in a social interaction, while exit phases are those in which a child takes leave from another by signalling an intention to leave. The occurrence of these phases is something that has been documented in other species. For example, in a recent paper, Heesen *et al*. [12] documented the presence and duration of entry and exit phases in play and grooming interactions in chimpanzees and bonobos. While entry phases occurred in 90% of bonobo interactions, they occurred in 69% of chimpanzee interactions. Entry phases in both species, lasted around 12 s on average. Exit phases occurred in 92% of bonobo interactions, compared with 86% of chimpanzee interactions and lasted on average around 14–17 s. Moreover, bonobos with closer relationships were less likely to produce entry and exit signals than those with more distant relationships, in line with what has been claimed for adult humans [13].

How do young children manage such coordination and how do they compare to our closest living relatives? Does their ability to engage in social interactions change over time? and how do their relationships affect the coordination process?

In recent years, there have been multiple experimental investigations of joint activities in young children, focusing on the capacity to engage in joint attention (e.g. [14]), in social games [15], their perception of joint actions as joint commitments [16–20] and recognizing joint intentions [21]. While the majority of these studies entailed having a child interacting with an adult experimenter, studies looking at interactions between peers show that it is only around the age of 2 years that children display an ability to coordinate with others (e.g. [22,23]). The general findings from the experimental literature therefore suggest that between the ages of 2 and 3 years, children undergo some major change in their appreciation of the social nature of joint activities and the norms and obligations that come with it. In particular, it is around that age that children orient to the existence of a joint commitment once they are engaged in an interaction with a partner. This appreciation of joint commitment can be observed behaviourally in their attempts to re-engage their partners if the joint action is suddenly interrupted, in their willingness to continue the task until both participants have obtained their reward and, in their tendency to account for their departure from the current joint task, to move on to another task with another social partner. Interestingly, a normative turn between the ages of 2 and 3 years is true not just for joint activities but several other domains such as their understanding of rules of games [24,25], property concerns (e.g. [26]) and the occurrence of overimitation (e.g. [27]). This would suggest a maturational change occurring around that age, inviting further investigations in naturalistic settings of how young children engage in social interactions, specifically before and after 3 years of age.

While most recent developmental research on social interactions in children has focused on experimental paradigms, earlier observational studies have focused on young children interacting with peers in natural settings (e.g. [28,29]). One key constraint of most of that research was the limited ability to rely on video footage for data collection and the reliance on ethograms and observers taking notes live. As such the vast majority of studies report on data per child that amounts to maximum 1 h, often no more than 5–10 min of observations collected at different ages (e.g. [30–32]), with few exceptions ([33,34], for example, collected up to 6 h of observational data longitudinally on the same child). Notwithstanding the limited amount of data on individual children, one common finding is that joint activity with peers is limited (they prefer to interact with adults, e.g. [35]), rudimentary in their second year of life, and achieves a certain degree of complexity only around 2 years of age [9]. Although it should be acknowledged that, more recently, some scholars have pointed out that interactions between peers during the first year of life probably play an important role in a child socio-emotional development (e.g. [36]).

In this paper, we provide a systematic investigation of the dynamic unfolding of spontaneous social interactions between peers in 2- and 4-year olds in preschools. By relying on methods mutated by primatology such as long-term focal observations across several days on the same subjects [37], we report on the frequency, duration and typology of social interactions young children engage in with their peers in a natural setting. Additionally, we consider the role played by several social variables in affecting the occurrence of signals that mark how they get into and out of social interactions. Among the social interactions we mostly focus on, there are different types of social play and conflict.

Social play is probably the most common type of joint activity that young children engage in. Studies focused either on how much daily time is spent engaged in play or quantifying solitary versus social play (e.g. [38]) or on the development of pretend play (e.g. [39]) as a proxy for symbolic cognitive abilities. One key interest of earlier observational studies was the ability of children to coordinate their actions and when they begin shifting from parallel play to social play to pretend play (e.g. [34]). Other scholars have investigated how young children fight over toys (e.g. [40–42]), the frequency of conflicts in children (e.g. [43]), how relationships (friendship and kinship) affect the likelihood of conflict in young children (e.g. [31,44]) and the role played by individual differences and parental socialization on how conflicts are resolved (e.g. [44,45]). Among the many things we know about conflict in young children, there is the fact that they mostly fight because of access to toys [46] or violation of personal space [47], the conflicts are short (between 15 and 24 s on average, [42,47]), and the frequency and duration of conflict between friends and non-friends is analogous, though they seem less intense with friends [31]. Interestingly, conflicts between friends tended to have similar starts compared to non-friends but different endings, like getting resolved through mutual disengagement in the case of friends. Also, many studies did not find any effect of gender on the frequency and duration of conflict (e.g. [31,48]).

While play and fighting both entail sustained interactions between two or more individuals, play is cooperative, requires a certain level of coordination obtained through repeated signalling and an understanding of the ultimate shared goal, while fighting is competitive and does not require communicative signals to be sustained. Therefore, investigating how play and conflict are initiated, maintained and ended might provide additional information concerning how the degree of 'jointness' of these social activities and their 'cooperative' versus 'competitive' underlying motivations can be observed in children's behaviour *in situ*. We will focus in particular on two types of social play: 'play without object' and 'play with object'. The first type will allow us to compare children's behaviours to those recently reported for bonobos and chimpanzees [12,49] while the second might display human-specific features of play and social interactions. These two types of play will be specifically compared to 'conflict', for an ecologically relevant comparison between play and conflict. In addition to play and conflict, we intend to track other types of social interactions commonly observed in children, like grooming (e.g. caressing someone's hair) or socio-physical touch (e.g. holding hands) and the frequency of conversation with peers.

This study combines exploratory and confirmatory components. From an exploratory perspective, we consider the frequency, duration and multi-party nature of several types of social interactions. We also consider the general sociability of 2- and 4-year-old children, the observable strength of their social bonds and investigate several factors that might play a role in the dynamic unfolding of social interactions (gender, party size, siblings, strength of social relationships, etc.)

From a confirmatory perspective, we formulate four general predictions based on the hypothesis that social interaction coordination is contingent on the development of theory of mind, language and social norm orientation. First, we predict that 4-year olds will be more likely than 2-year olds to engage in social play. Second, we predict that the number of social partners (partner quantity/social experience) and the strength of the relationship with the partners (level of friendship) will modulate the occurrence of entry and exit phases during social interactions, so that a higher number of social partners and a stronger friendship should correlate with fewer entry and exit phases. Third, we predict that 4-year olds will be less likely than 2-year olds to engage in social conflicts. Fourth, we predict that there will be more entry and exit phases in play than in conflict, i.e. they will be more likely than in conflicts to elicit the gaze behaviour of the recipient, to produce communicative signals that convey their intentions to engage in the social interaction and to communicate an intention to end the activity before doing so. Accordingly the behaviour during conflicts will probably be unilaterally directed, mostly insensitive to the attention and intentions of the recipient and its closing will most likely be achieved by a unilateral abandonment of the fight.

2. Methods

(a) Subjects and schools

Participants were 31 children attending four preschools in the same county in southern California. There were fourteen 2-year olds ($M = 28.7$ months, s.d. = 2.75; six boys) and seventeen 4-year olds ($M = 51.3$ months, s.d. = 2.56; 11 boys), where age refers to the age on the first day of observation. The sample was 35% ($n = 11$) European American, 6% ($n = 2$) Hispanic, 13% ($n = 4$) multi-ethnic and 45% ($n = 14$) parents declined to provide race or ethnicity information in the demographic form. Seventeen of the 31 children had siblings. Children with siblings had a mean of 1.12 siblings (s.d. = 0.31). 29.5% of focal children with siblings ($n = 5$) were the oldest child among their siblings and 70.5% ($n = 12$) were the youngest child among their siblings. There were no reported middle children.

All four preschools in which data was collected allowed children several hours of free play during the day. During free play, children would be interacting with several children of different ages. All preschools provided both outdoor and indoor spaces for free playing opportunities. During free play sessions (i.e. outside of specific curricula led by a teacher), teachers' interventions were usually limited to assisting in resolving conflicts if they escalated and monitoring children for safety.

(b) Data collection

We conducted focal observations on individual children between May 2017 and June 2018. Each focal subject was followed for a total of 20 h (in 6 out of 31 children, data collection had to be shortened to approximately 10 h because the child left the school during the time longitudinal data was being collected or was not present for several data collection sessions). A total of 563 h of video footage was collected. Usually, data collection on the same child would occur 2–3 times a week, leading to a focal follow on the same child lasting between 5 and 10 weeks total. No child was focal followed for more than 1 h per day.

We filmed the children using digital high-definition cameras (Canon Vixia HF G40 or Canon Vixia HF R800) and when possible relying on a directional shotgun microphone (Sennheiser MKE 600). We filmed the children always during free play time, to maximize comparability of the data across the four schools.

(c) Video coding procedure

We coded the videos collected through ELAN 6.2 [50], a video annotation software designed to facilitate the annotation of multimodal data. Given the shortened data collection for 6 out of the 31 subjects, we coded for social interactions in 10 h of observation of each subject (or the amount available for each child, in some cases slightly less). Specifically, we coded for the

Table 1. Definition of social interaction types identified in the dataset.

social interaction type	definition
play with object	focal child will *jointly/take turns* with another child engaging in conversation, singing, dancing, chasing, hiding, racing, tagging, pretend play or rough-housing while interacting with the same objects
	there must be clear communication between the focal child and the other child/children (i.e. they are not engaged in parallel play with the same object)
play without object	focal child will *jointly/take turns* with another child engaging in conversation, singing, dancing, chasing, hiding, racing, tagging, pretend play or rough-housing
	there must be clear communication between the focal child and the other child/children (i.e. they are not engaged in parallel play)
social-physical touch	focal child makes affiliative physical contact with another child (e.g. holding hands, high fiving, tapping shoulder to get attention, etc)
grooming	focal child's hair is touched (e.g, stroking, brushing hair, etc.) and/or moved around (e.g. sculpting a hairstyle) with either hands or with an object (e.g. brush, comb, fork, etc.) OR the focal child touches and moves another child's hair
conversation	focal child and another child are reciprocally engaged in vocal communication. This will be coded only when conversation does *not* occur during other joint activities here identified and when at least one verbal utterance by one child is responded to by the other child
	if focal and classmate converse while engaged in any other joint activity coded for this study (e.g. play, conflict and grooming), this is coded with the label of the larger activity they are part of (e.g. play with object) and not as conversation
conflict	when the focal child and another child disengage from cooperative/neutral behaviour and cannot reconcile opposing goals or interest in a toy without protest or physical interruption. Often accompanied by a change in register in both children (e.g. using more aggressive or diplomatic language to resolve the conflict) and a change in body language (e.g. nonverbal cues that show the child is upset or sad. Some examples include: crossing arms, hanging their head, scowling and covering their face)
	the behaviour must be exhibited by both children to count as 'conflict'. If one child ignores the other, it is not considered as a social interaction

frequency and duration of six different social interaction types (see table 1 for definitions). We excluded any social interaction lasting less than 3 s. We also identified the interactional partner of each focal subject for each social interaction event. For five out of the six social interaction types (excluding conversation), we further coded the occurrence of an entry phase, a main phase and an exit phase drawing on the same coding method as in [12], to ease comparability of the results to what is observed in non-human primates. The coding of approximately 310 h of data led to the identification of 4019 total social interactions. Moreover, we further coded a subset of five out of six social interaction types (excluding conversation) for the occurrence of entry, main and exit phases and their durations. Specifically, we further coded 585 social interactions, amounting to approximately 27% of the social interactions available within that subset of social interaction types.

Following [12], we defined an entry phase as 'the process by which partners recruit each other, via mutual gaze exchanges and intentional communicative signals (for intentionality criteria, see [51]) to determine the type of the activity, negotiate its temporal and spatial properties and potentially establish joint commitment. Because to enter a social interaction, both partners need to mutually agree to it, entries are always achieved through (at minimum) the exchange of mutual gaze (i.e. both partners simultaneously look at each other's face) but can also include other signals such as gestures or vocalizations (e.g. greetings). If partners did not engage in mutual gaze exchanges and did not produce any other communicative signal before engaging in the activity itself, the entry phase was coded as absent'. [12, p. 17] In other words, the occurrence of mutual gaze alone or just greetings between the children without mutual gaze was sufficient for that social interaction to be coded as having an entry. We defined an exit phase as 'the process by which partners […] take leave of each other. They may express intentions to end a social interaction via intentional communicative signals or other specific behaviors before walking away. […] If partners did not engage in gaze exchanges and did not produce any other communicative signal before leaving their partner, the exit phase was coded as absent' [12, p. 17]. The main body phase consisted in the movements typical of the joint activity, such as chasing each other for play or holding hands for socio-physical touch. The main body phase could occur without the occurrence of an entry or an exit phase.

Before proceeding with coding, all coders had to pass a reliability threshold. After some initial training on definitions, coders were asked to code all instances of social interaction first and later phases on the same two 30 min videos from different children that were part of the data not meant to be coded for social interactions. A laboratory manager had previously coded these videos as well and that performance was taken as the standard. The research assistants were selected for further coding of the behavioural data if they passed a threshold of 70% agreement with the laboratory manager in terms of identifying the presence of a social interaction within 5 s of when it had been identified by the laboratory manager and whether they had labelled it as the same type of social interaction. Five out of six coders passed the threshold (ranging in performance between 71.2% agreement, $K = 0.63$ to 81% agreement, $K = 0.75$) and then proceeded to code 310 h of video data. The coder excluded had obtained a score of 54.6%, $K = 0.42$.

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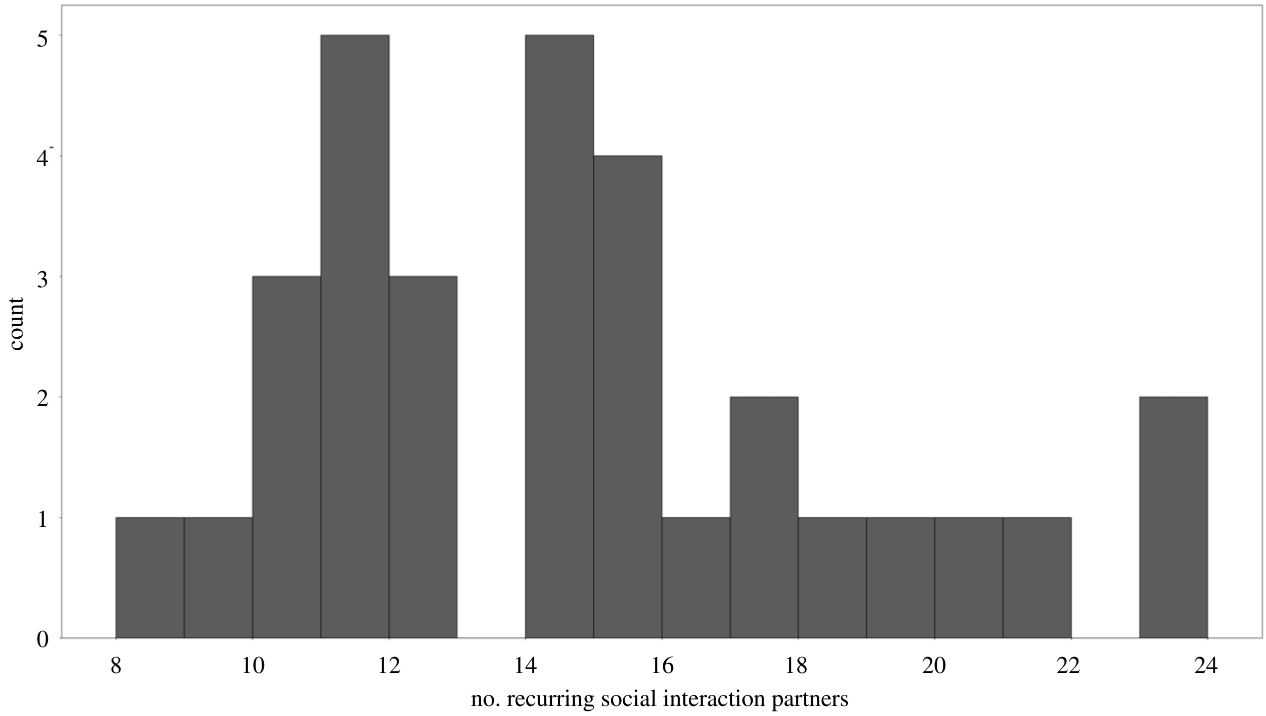

Figure 1. Distribution of the number of recurring social interaction partners for each focal child (NRP score). Mean = 14.29 repeat partners, s.d. = 4.07.

(d) Statistical analysis

This study considered six social interaction types resulting in 4019 total social interactions: conversation ($n = 1859$, 46% of dataset), play with object ($n = 1229$, 30% of dataset), play without object ($n = 508$, 13% of dataset), social-physical touch ($n = 223$, 5% of dataset), conflict ($n = 219$, 5%) and grooming ($n = 16$, less than 1% of dataset). A randomly selected subset of these social interactions was coded for entry/main body/exit phases resulting in 585 fully annotated activities which did not include conversation: play with object ($n = 338$, 54% of subset), play without object ($n = 144$, 23% of subset), social-physical touch ($n = 65$, 11% of subset), conflict ($n = 62$, 11%) and grooming ($n = 6$, 1% of subset). The subset coded for phases included both dyadic and multi-party social interactions.

Statistics were calculated with python v3.8 using the *GLM* function in the statsmodels package v.12 and with R v.4.1.2 using the *glmer* in the package lme4 v.1.1.12. We ran ordinary least-squares regression (OLS) to examine sources of variation in (i) the rates that children engage in joint activities and (ii) the relative time children engage in joint activities. For these two statistical analyses, data were aggregated per child and activity type, so we did not need to account for multiple comparisons. We ran a linear mixed model (LMM) to examine sources of variation in (iii) main body phase durations. We ran generalized linear mixed models (GLMMs) with binomial error and the logit link function to examine sources of variation in (iv) the presence of entry and exit phases. For all models we considered age group, gender and the activity type (using play with object as our reference treatment) as independent variables. For models (iii) and (iv), focal child identity (ID) and partner ID were included as random effects. For models (iii) and (iv) we additionally considered the activity group size (how many participants were engaged in a social interaction) (min = 2, max = 7), whether the focal child had siblings (true or false), the relative dyad co-occurrence (RDC) and number of recurring partners (NRP). RDC (min = 0.002, max = 0.490) is a proxy for closeness of relationship/friendship and is defined as

$$\mathrm{RDC}(p_i, p_j) = \frac{JA(p_i, p_j)}{JA(p_i)},$$

where p_i is a participant. $JA(p_i)$ is the number of social interactions. p_i was involved in. $JA(p_i, p_j)$ is the number of social interactions both p_i and p_j were involved in. When there were more than two children in a social interaction, we used the maximum RDC score between the focal child and other children. RDC represents how frequently a child is interacting with the focal child out of the total social interactions that the focal child participates in. NRP (min = 8, max = 24) is a proxy for social experience and is defined as the number of distinct partners a focal child interacts with more than once (partner quantity). We computed RDC and NRP using a subset of the dataset that includes all 3835 positive social interactions, i.e. all conversation, play with object, social-physical touch and grooming but no conflict.

3. Results

(a) Descriptive statistics

(i) Social partners

First, we report on the type of sociality we have identified in the children participating in this study. On average, within the 10 h of data coded for social interactions, children engaged with 14.29 repeated partners, i.e. social partners they engaged with more than once during that time. The range extending from a minimum of eight social partners to a maximum of 24 (figure 1).

When we look at the frequency focal subjects interacted with each of these social partners, a clear pattern emerges: the vast majority of children have several social partners they interact rarely with and one to two individuals they interact much more often than anyone else. This is true for both boys and girls and for both 2- and 4-year olds. We can think of these individuals as focal subjects' closest friends [52]. Specifically, 25 out of 31 children had at least one partner with whom they interacted in more than 25% of the total social interactions they engaged in, which represents the equivalent of the mean dyad co-occurrence in terms of social interaction + 2 s.d. (see figures 2 and 3). Boys mean

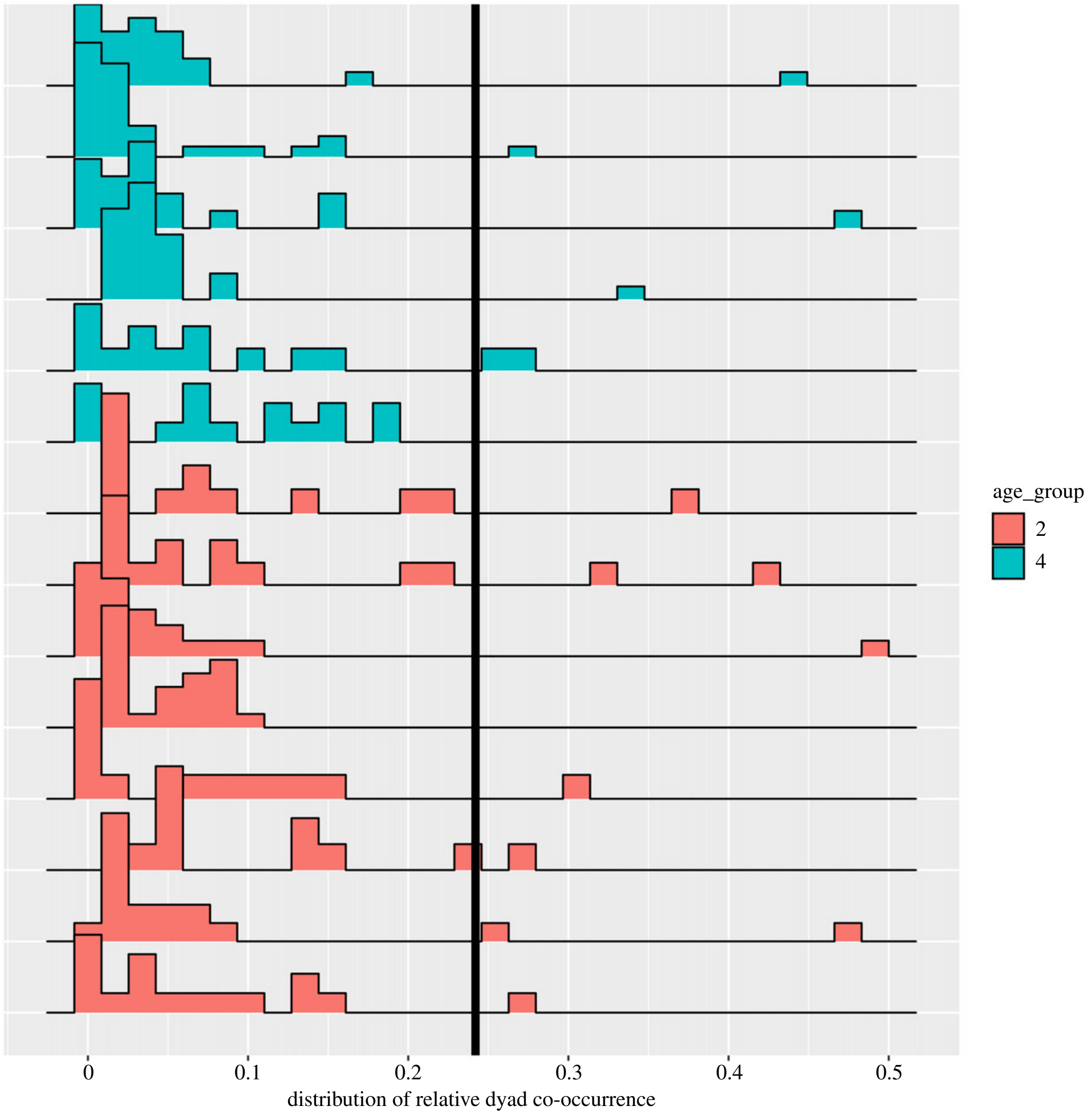

Figure 2. Ridgeplot showing distributions of RDC for each boy. The black vertical line indicates an outlier threshold (mean + 2 s.d. = 0.242) where mean and s.d. are computed over RDC for all focal children after removing outliers using the outliers R package. The individuals on the right of the black vertical line are the close friends. (Online version in colour.)

RDC was 0.074 ± 0.088 with a minimum of 0.003 and a maximum of 0.485. Thirteen of 17 focal boys had at least one partner above the outlier threshold. Focal boys had a mean of 1.6 ± 0.518 partners above the outlier threshold. Girls mean RDC is 0.067 ± 0.088 with a minimum of 0.002 and a maximum of 0.494. Twelve of 14 focal girls had at least one partner above the outlier threshold. Focal girls had a mean of 1.25 ± 0.452 partners above the outlier threshold.

Overall mean RDC is 0.070 ± 0.08 with a minimum of 0.002 and a maximum of 0.493. Twenty-five of 31 focal children had at least one partner above the outlier threshold. Focal children had 1.36 ± 0.489 partners above the outlier threshold.

The individuals on the right of the black vertical line are the close friends.

We then considered the frequency with which the social interactions performed by 2- and 4-year olds were dyadic, versus multi-party (table 2). Overall, 82.7% of social interactions were performed dyadically with little difference between 2- and 4-year olds (84.6% versus 81.6%). Notably while almost all conflicts and social-physical touch were performed dyadically, a quarter of play events occurred with more than two participants at a time.

(ii) Social interactions

From the 4019 social interactions, we observe that on average, individuals engaged in 13.36 (±7.23) social interactions per hour (figure 4).

(b) Statistical models

(i) Effect of age and gender on likelihood of engaging in different types of social interactions

To test our first prediction (older children will be more likely to engage in social play than younger ones), we examined whether children of different ages and genders engage in social interactions at different rates (defined as the number of social interactions per hour) and whether these rates differed by activity type. We aggregated over the dataset of 4019 social interactions to determine the number of social

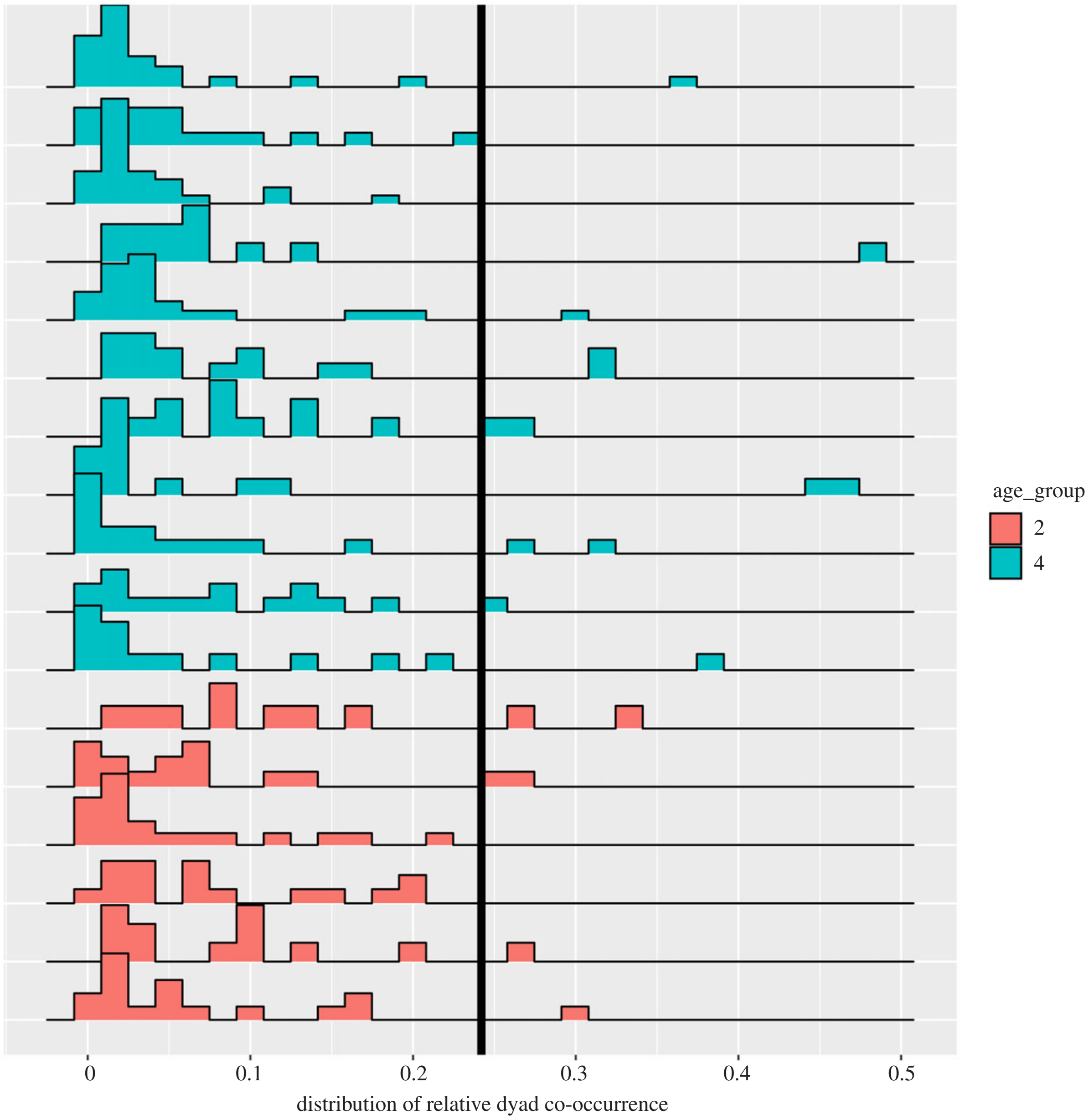

Figure 3. Ridgeplot showing distributions of RDC for each girl. The black vertical line indicates an outlier threshold (mean + 2 s.d. = 0.242) where mean and s.d. are computed over RDC for all focal children after removing outliers using the outliers R package. (Online version in colour.)

Table 2. Proportion of social interactions performed dyadically.

	2 years old		4 years old		
	female	male	female	male	total
conversation	88.2	88.9	83.8	86.5	86.3
play with object	83.1	75.7	75.4	79.1	78.5
play without object	71.9	77.6	64.9	69.3	70.5
social-physical touch	87.0	92.7	91.4	91.0	90.5
grooming	100.0	100.0	71.4	66.7	75.0
conflict	94.8	97.6	96.4	98.6	96.8
	2 years old		4 years old		total
	84.6		81.6		82.7

interactions per hour for each child per activity type, resulting in 161 rates. Using OLS regression, we tested sources of variation in these rates. The results of the model indicate the predictors explained 51.8% of the variance (pseudo-$R^2 = 0.558$, $\chi^2 = 86.6$). In line with our first prediction, we found a significant effect of age group ($\beta \pm$ s.e. $= 0.177 \pm$

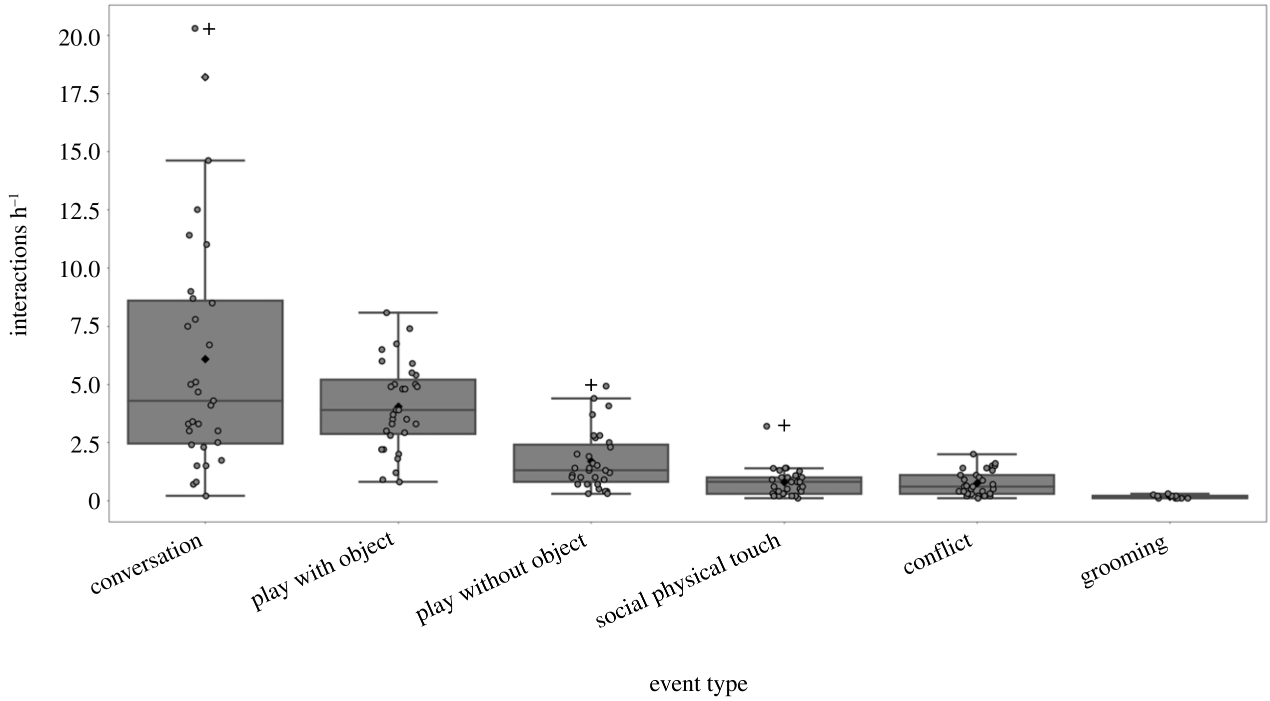

Figure 4. Social interactions per hour for each activity type. Shown are individual rates (grey dots), population means (filled diamonds), medians (horizontal lines), quartiles (boxes), percentiles (5% and 95%, vertical lines) and outliers (black crosses).

0.061, $z = 2.918$, $p = 0.001$), with older children engaging in more joint activities. Moreover, we found children engage in different joint activity types at different rates compared to play with object: conversation (0.630 ± 0.191, $z = 3.300$, $p = 0.001$), play without object (−0.729 ± 0.191, $z = -3.814$, $p < 0.001$), social-physical touch (−1.013 ± 0.194, $z = -5.210$, $p < 0.001$), conflict (1.008 ± 0.194, $z = -5.187$, $p < 0.001$) and grooming (−1.261 ± 0.274, $z = -4.598$, $p < 0.001$). There was no significant effect of gender (0.042 ± 0.122, $z = 0.342$, $p = 0.691$). This means that children engage in more conversations per hour than in social interactions involving play with objects, but fewer social interactions involving play without object, social-physical touch, grooming or conflict compared to play with object.

Figure 5 shows the frequency of social interactions broken down by age group, gender and activity type.

(ii) Effect of age group, gender and activity type on relative time engaged in social interactions

We further tested whether children of different ages and genders spend different amounts of time engaged in social interactions (as measured by the sum of social interaction durations divided by total coded observation time) and whether these durations differ by activity type. We aggregated over the dataset of 4019 social interactions to determine the total duration of social interactions relative to observation duration per child per activity type, resulting in 161 relative durations. Using OLS regression, we tested sources of variation in these relative durations. The results of the model indicate the predictors explained 50.2% of the variance (pseudo-$R^2 = 0.558$, $\chi^2 = 86.7$). We found a significant effect of age group (β ± s.e. = 0.150 ± 0.061, $z = 2.473$, $p = 0.031$), with older children engaging in joint activities longer than younger children. Moreover, we found children engage in different joint activity types at different rates compared to play with object: grooming (−1.800 ± 0.274, $z = -6.559$, $p < 0.001$), social-physical touch (−1.701 ± 0.194, $z = -8.747$, $p < 0.001$), conflict (−1.646 ± 0.195, $z = -8.462$, $p < 0.001$), play without object (−1.200 ± 0.191, $z = -6.288$, $p < 0.001$) and conversation (−0.565 ± 0.191, $z = -2.953$, $p = 0.003$). Despite engaging in 50% more conversations, children spend more time playing with objects (table 3). There was no significant effect of gender (−0.092 ± 0.122, $z = 0.755$, $p = 0.450$).

From the 4019 social interactions, we observe that the average social interaction lasted 27.52 (±22.80) seconds (including entry and exit phases, as well as the main body phase) and individuals spend on average 11.28% (±6.57%) of their time engaged in joint activities (see table 3 and figure 6 for detailed results broken down by age group, gender and activity type).

(iii) Durations and rates of social interaction entries and exits

Having reported on frequency and duration of social interactions and on the number of social partners and different types of relationships between children, we can now consider the way they start and the way they end. Two-year olds and 4-year olds signalled entries at similar rates: 66.3% and 69.0% of social interactions, respectively. The average duration of an entry phase was 2.97 s for 2-year olds and 2.93 s for 4-year olds.

Two-year olds and 4-year olds signalled exits at similar rates: 69.3% and 75.5% of social interactions, respectively. The average duration of an exit phase was 2.56 s for 2-year olds and 2.27 s for 2-year olds (tables 4 and 5).

(iv) Factors affecting the presence of entries and exits

Next, to test our second prediction (the number of social partners and strength of social bond will affect the occurrence of entry and exit phases), we examined whether the occurrences of entry and exit phases differed across age groups, genders, activity types, activity group sizes, NRP, RCD and whether the focal child had siblings. To test this, we used two GLMMs (one for entries and one for exits) with binomial error and logit link function for these sources of variation in

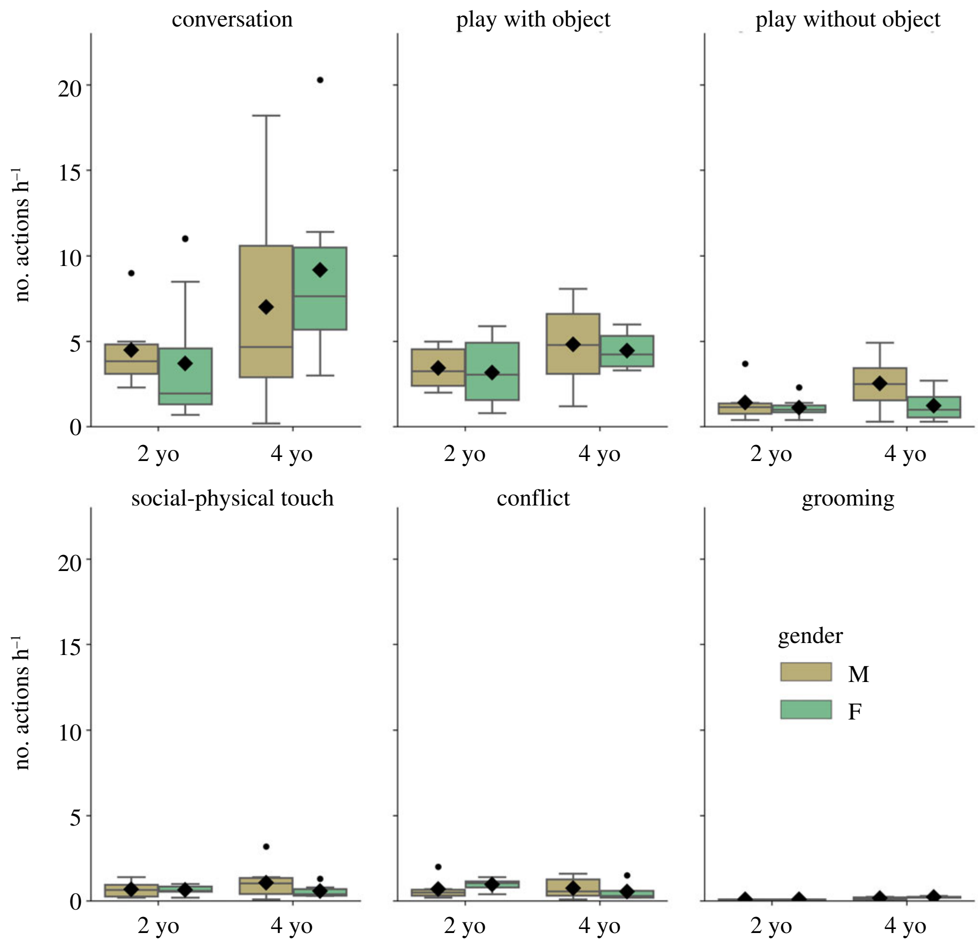

Figure 5. Social interactions per hour in relation to age, gender and activity type. Shown are population means (filled diamonds), medians (horizontal lines), quartiles (boxes), percentiles (5% and 95%, vertical lines) and outliers (filled dots). (Online version in colour.)

Table 3. Average duration (seconds) of social interactions in relation to age group, gender and activity type.

	2 years old				4 years old					
	female		male		female		male		total	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
conversation	19.45	5.36	22.20	15.25	21.04	4.63	21.61	8.06	21.06	8.47
play with object	49.03	30.63	44.23	34.35	43.62	29.70	46.86	17.70	46.29	25.91
play without object	32.91	28.65	28.24	8.38	47.87	50.76	37.74	23.64	36.61	29.37
social-physical touch	12.63	5.77	11.15	4.59	12.58	7.43	10.18	4.33	11.47	5.29
conflict	18.16	5.67	22.55	19.44	20.08	12.36	21.18	11.49	20.44	11.93
grooming	30	n/a	61	53.74	26.66	11.93	12.87	9.47	28.35	26.96

entries and exits. We excluded instances of grooming owing to the limited number of observations of this activity type.

Contrary to our prediction, we found no significant effects on the presence of entries (table 6). We also found no effects on the presence of exits (table 7).

(v) Factors affecting main body phase duration

Next, we tested whether main body phase durations differed across age groups, genders, activity types, activity group sizes, NRP, RDC and whether the focal child had siblings. We used an LMM to test sources of variation in main phase duration. If there were multiple other children involved in a joint activity, we used the greatest RDC score between the focal child and other children. The results of the model indicate the predictors explained 17% of the variance (pseudo-$R^2 = 0.172$, $\chi^2 = 438$).

We found a significant effect of activity group size on main body phase duration ($\beta \pm$ s.e. $= 0.339 \pm 0.060$, $t = 5.625$, $p < 0.001$), meaning that children engaged in longer social interactions when there were more than two partners involved. We found a significant effect of gender: compared to girls, boys engaged in shorter social interactions (-0.254 ± 0.117 $t = -2.169$, $p = 0.043$). We also found a

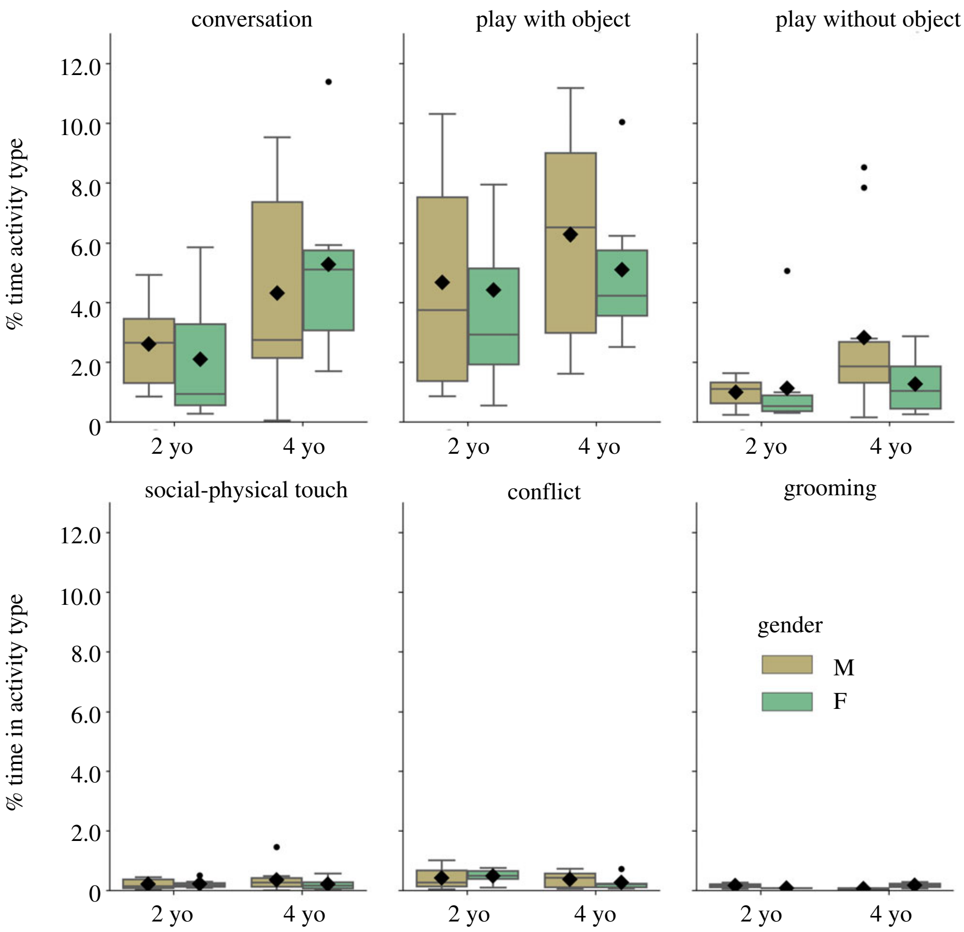

Figure 6. Per cent of time spent engaged in social interaction in relation to age, gender and activity type. Shown are population means (filled diamonds), medians (horizontal lines), quartiles (boxes), percentiles (5% and 95%, vertical lines) and out liners (filled dots). (Online version in colour.)

Table 4. Proportion of social interactions that contain entry by age, gender and activity type.

	entry				
	2 years old		2 years old		
	female	male	female	male	total
play with object	67.7	67.6	76.0	74.6	71.9
play without object	68.7	84.0	54.1	71.3	69.8
social-physical touch	54.7	48.6	77.7	56.1	58.7
conflict	56.2	81.6	85.0	78.5	74.1
grooming	100.0	n/a	33.3	50.0	50.0
	2 years old		4 years old		total
	66.3		69.0		67.8

significant effect of NRP (-0.036 ± 0.016, $t = -2.306$, $p = 0.032$), meaning that children who had more repeated partners engaged in shorter social interactions. Additionally, we found a significant effect of activity type. Compared to play with object, social-physical touch was associated with shorter social interactions (-0.926 ± 0.144, $t = -6.451$, $p < 0.001$) as was play without object (-0.239 ± 0.106, $t = -2.254$, $p = 0.025$).

(vi) Effects of main body duration

Next, we tested whether exit phases were less common when the duration of the main body phase of a social interaction was longer. We used a GLMM with binomial error and logit link function to test sources of variation. We found a significant effect of the log duration of the main body phase on the presence of exits ($\beta \pm \text{s.e.} = -0.205 \pm 0.094$, $z = -2.189$, $p = 0.029$). This means that when social interactions have longer main body phases, focal children are less likely to coordinate an exit phase when disengaging from interactions.

(vii) Factors affecting conflict

Focusing specifically on conflict and to address our third prediction (older children will be less likely to engage in conflict

Table 5. Proportion of social interactions that contain exit signals by age, gender and activity type.

	exit				
	2 years old		4 years old		
	female	male	female	male	total
play with object	75.4	75.7	64.2	69.6	71.2
play without object	54.2	88.9	79.4	31.1	74.9
social-physical touch	73.8	90.2	75.0	84.3	81.1
conflict	44.7	56.6	50.0	74.0	58.2
grooming	100.0	n/a	100.0	100.0	100.0
	2 years old		4 years old		total
	69.3		75.5		72.7

Table 6. GLMM estimates entries. Estimates of social interactions types are with respect to play with object.

	estimate	s.e.	*z*-value	Pr(>|z|)
(intercept)	0.134	0.636	0.211	0.833
conflict	−0.049	0.317	−0.154	0.878
play without object	−0.236	0.231	−1.022	0.307
social-physical touch	−0.536	0.300	−1.784	0.074
age group	0.123	0.142	0.863	0.388
gender[M]	0.104	0.267	0.390	0.697
RDC	0.679	0.824	0.824	0.410
NRP	0.001	0.035	0.021	0.983
has sibling	−0.070	0.264	−0.266	0.790
group size	0.145	0.130	1.110	0.267

Table 7. GLMM estimates exits. Estimates of social interaction types are with respect to play with object.

	estimate	s.e.	*z*-value	Pr(>|z|)
(intercept)	1.024	0.617	1.660	0.097
conflict	−0.404	0.305	−1.324	0.185
play without object	0.154	0.241	0.642	0.521
social-physical touch	0.282	0.329	0.858	0.391
age group	0.022	0.138	0.160	0.873
gender[M]	0.452	0.255	1.771	0.077
RDC	−0.273	0.814	−0.335	0.738
NRP	−0.038	0.033	−1.146	0.252
has sibling	0.211	0.254	0.831	0.406
size	0.036	0.127	0.285	0.776

compared to younger ones), we investigated age group, gender, activity group size, NRP, greatest RDC and whether the focal child had siblings as sources of variation between instances of conflicts and other cooperative joint activity types. To test this, we used a GLMM with binomial error and a logit link function. Our dependent variable was whether or not an interaction was a conflict ($y = 1$) or not ($y = 0$).

In line with our third prediction, we found a significant effect of age group in discriminating between conflicts and non-conflicts ($\beta \pm$ s.e. $= -0.433 \pm 0.192$, $z = -2.260$, $p = 0.024$), meaning that 4-year olds were less likely to engage in conflicts than 2-year olds. We also found a significant effect of NRP (0.087 ± 0.041, $z = 2.124$, $p = 0.034$) meaning that children who overall interacted with more children were more likely to engage in conflicts. Additionally, we found a significant effect of greatest RDC (-7.688 ± 2.150, $z = -3.417$, $p = 0.001$), meaning that children are less likely to engage in conflicts with those they interact more frequently with (their friends).

To address our fourth prediction (that conflicts would have less entry and exit phases than other cooperative social interactions), we examined whether the occurrences of entry and exit phases differed across age groups, genders and whether an activity was a conflict or non-conflict. To test this, we used two GLMMs (one for entries and one for exits) with binomial error and logit link function for these sources of variation in entries and exits. For additional clarity, unlike the model testing hypothesis (iii), in which conflict was a predicted variable, in these models testing hypothesis (iv), conflict is treated as a binary predictor variable, e.g. conflict = 1 or conflict = 0.

Contrary to our fourth prediction, we found no significant effect of conflict on likelihood of a social interaction event to have an entry (0.017 ± 0.300, $z = 0.055$, $p = 0.956$), while controlling for age, gender and focal child and partner ID. Conflict does not have a clear effect on exit either (-0.529 ± 0.288, $z = -1.832$, $p = 0.067$). Finally, gender does not appear to affect likelihood of conflict in preschoolers (0.457 ± 0.256, $z = 1.784$, $p = 0.074$).

4. Discussion

Towards investigating the development of the human interaction engine, this paper has focused on the factors affecting how and how often 2- and 4-year-children engage in social interactions with peers. Combining the results across the two ages, we found that overall young children engage in social interactions frequently (on average 13 times per hour), often with more than one partner (in almost 20% of cases) and with several different social partners. These social interactions are often brief (on average 28 s), and contrary to expectations they do not have entry and exit phases as frequently as reported in great apes [12]. They engage mostly in conversation and social play with objects and these two social interactions are also the ones with the longest duration. This produces several opportunities for children to practise how to enter and exit social situations because of many fast-paced interactions with a diverse pool of social partners. While the Interaction Engine Hypothesis does not make any specific claim about the importance of number of social partners towards the development of human-like interactional ability, we would like to suggest that it might actually be an important variable. Recent anthropological work on tool making has shown for example that while hunter–gatherer men like Hadza and Ache might observe at least 300 others create tools in a life time, male chimpanzees are likely to observe no more than 20 other males because of their xenophobia (see [53]). The claim there was that diversity in models leads to improved social learning opportunities, innovation and cumulative culture. Similarly, it is likely that young human children interact with more social partners by the age of 4 years than the average chimpanzee in a lifetime (though further empirical evidence is needed). This environmental exposure to diverse partners, and the difficulty of navigating the range of familiarity and social relationships children might have with those partners, would lead to the need to carefully coordinate signalling and monitoring each other's behaviour.

When we look at our original predictions concerning the development of social interactional abilities in preschoolers, we find that in line with our first prediction, 4-year olds engage in cooperative social interactions more often than 2-year olds. An increased successful engagement in social interactions is in line with the expectation that older children would be able to better predict the behaviour of their partners, align their conduct with them and signal their intention to start or end a joint activity. Cognitive development probably facilitates the ability of parsing others' behaviour and coordinating with them. Surprisingly, however, and in contrast with our second prediction, social experience and strength of social relationship do not seem to play any role in the sequential unfolding of social interactions (both cooperative and competitive ones), in particular in terms of affecting the likelihood of having an entry or exit phase.

In line with our third prediction, 2-year olds fight more than 4-year olds and conflict is affected by the number of repeated social partners (the more you have, the more likely you are to fight) and children are less likely to fight with close friends than with other children. More social partners often means more individuals that the child rarely interacts with. On the other hand, repeated interactions with the same social partner can lead to both an ability to better read the conduct of the other and predict what they are going to do next, and an increased motivation to care for the social partner and therefore an interest in limiting the chances of conflict. Almost all 2- and 4-year olds have one or two close friends they interact often with and the number of close friends does not seem to be affected by gender. In contrast with our fourth prediction we find that conflicts are as likely as cooperative social interactions to have entry and exit phases, practically disconfirming that unilateral disengagement is more likely in conflicts compared to play situations.

Concerning frequency and duration of conflicts, Hay [54] reports conflicts occurring on average eight times per hour. Dawe [41] reports that conflicts are short, approximately 24 s on average and Houseman [55] reports even shorter average duration, approximately 12 s. While the duration of conflicts in our dataset (20.4 s) is analogous to what is reported by Dawe, the frequency of conflict is significantly smaller, with less than one conflict per hour identified. The main reason for this difference probably comes from the way we identify conflict. In our study only conflict that is ratified by a recipient and that leads to social interactions would count. As such, situations in which one child might yell at the other or even push the other to the ground without getting a response would not be considered in our analyses.

Similarly to what has been reported in earlier observational studies on play and conflict in toddlers, gender appears to have little to no effect on social interaction frequencies and durations but it has an effect on duration of the main phase, with girls engaging in social interactions with longer main phases compared to boys. Noticeably, social interactions with longer main phases are less likely to show exits and main body phases tend to be longer when more children are involved. In our dataset, about 25% of play activities involve more than two children, once again confirming the hyper-sociality of human children in line with the Interaction Engine Hypothesis.

The most noticeable finding here is the fact that only two-thirds of social interactions have entry and exit signals (66–69%), similar to what was reported for chimpanzees but noticeably less than what was reported for bonobos (more than 90%). The fact that social relationship does not appear to modulate the occurrence of entry or exit signals in young children is also analogous to what observed in chimpanzees and yet different from what was claimed both for bonobos [12] and for human adults [13], although precise quantitative studies in naturalistic settings are lacking for adult humans. All of the above suggests that at least in young children, social relationships and the specific motivation to engage in social interactions, be it cooperative like in play or competitive like in conflict, might not be particularly important for the process through which social interactions are accomplished. It is also possible that for young children, engaging in play or conversation with peers entails less sharedness of goals and joint commitment than noted in experimental settings and as such more similar to what is observed in chimpanzees. Note also that it is possible that in the preschool context, children were familiar enough with each other to make the occurrence of entries and exits much less necessary when compared with interactions with peers who are real strangers (i.e. never met before). This would suggest that we are underestimating the effect of social relationship because the range we are measuring is not wide enough. Further empirical studies will need to address this potential alternative explanation.

Surprisingly the proportion of social interactions with entry and exit phases are practically identical across the two age groups. This proportion potentially suggests that the occurrence of such phases and the signalling associated with them might be less normative than originally predicted (a norm that is followed only two-thirds of the time does not have very normative power). It is likely that other specific situational factors can account for when entries and exits would actually occur, and those factors could probably be when the two individuals had most recently interacted and the valence of that interaction. Such relational factors have for example been shown to be relevant for the occurrence of attempts at food transfers in orangutans (see [56]) and the selection of which signals to use [57]. It is also possible that young children's signal production is affected by their reading of the social situation as a 'continuing state of incipient talk' [58], i.e. social situations in which interactional lapses can occur between participants but that do not require renewed exchanges of greetings, for example because participants remain perceptually accessible to each other (e.g. two people sitting side by side on a plane or watching a show). In this sense, similarly to what has been described for adult humans, if child A and child B have been playing together for a while but then moved to solo activities for a few minutes before interacting again, they might be thinking of the solo activities as interruptions of a larger social play activity with that specific partner. Given that our focal data was not always collected at the very beginning of the school day and we do not have access to all social interactions between a focal child and all other partners within a day, this remains a working hypothesis.

Overall, we believe we have provided a fine-grained picture of the extent to which 2- and 4-year olds spontaneously engage in social interactions with peers in preschools and the several factors that appear to affect social interaction as a process. While the number of focal subjects is limited, the amount of hours of video recordings on each subject is much higher than anything previously reported in similar settings. While more longitudinal and extensive data collection is certainly necessary, the current data, collected and coded with the same methods recently adopted for chimpanzees and bonobos allow for a more ecologically valid comparison between the species. We believe this is supporting evidence for the Interaction Engine Hypothesis in that, compared to our closest living relatives, already at a young age humans engage in social interaction more frequently and at a much faster pace than non-human great apes do, interacting with a remarkable number of partners. It remains to be assessed to what degree the limited role played by social experience/partner quantity and strength of social relationships in the unfolding of social interactions in young children is owing to more limited social competence, or rather we have overestimated the degree to which adult humans are affected by those same variables in naturally occurring interactions. Ultimately, the data show that at a very young age, humans already manifest a remarkable motivation and skillset for engaging in social interaction that might constitute the hallmark of what distinguishes us from our closest living relatives.

Ethics. All work here conducted was approved by the University of California, San Diego Human Research Protections Program as part of a larger research programme conducted by the Comparative Cognition Laboratory directed by F.R. (Project ID: no. 161452SX).

Data accessibility. The datasets supporting this article are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.dr7sqvb0z [59].

The data are provided in the electronic supplementary material [60].

Authors' contributions. F.R.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision and writing—original draft; J.T.: formal analysis, methodology, visualization and writing—original draft; A.B.: conceptualization, funding acquisition, methodology, supervision, writing—review and editing; E.G.: conceptualization, methodology, writing—review and editing; R.H.: conceptualization, methodology, writing—review and editing; K.Z.: conceptualization, funding acquisition, methodology and supervision.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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References

1. Schegloff EA. 1996 Turn organization: one intersection of grammar and interaction. *Studies Interactional Socioling.* **13**, 52–133. (doi:10.1017/cbo9780511620874.002)
2. Levinson SC. 2006 On the human 'interactional engine'. In *Roots of human sociality: culture, cognition and interaction* (eds NJ Enfield, SC Levinson), pp. 39-69. Oxford, UK: Berg.
3. Levinson SC. 2019 Interactional foundations of language: the interaction engine hypothesis. In *Human language: from genes and brain to behavior* (ed. P Hagoort), pp. 189–200. Cambridge, MA: MIT Press.
4. Clark HH. 1996 *Using language*. Cambridge, UK: Cambridge University Press.
5. Bangerter A, Clark HH. 2003 Navigating joint projects with dialogue. *Cogn. Sci.* **27**, 195–225. (doi:10.1207/s15516709cog2702_3)
6. Sebanz N, Bekkering H, Knoblich G. 2006 Joint action: bodies and minds moving together. *Trends Cogn. Sci.* **10**, 70–76. (doi:10.1016/j.tics.2005.12.009)
7. Bratman ME. 1992 Shared cooperative activity. *Phil. Rev.* **101**, 327–341. (doi:10.2307/2185537)
8. Milward SJ, Kita S, Apperly IA. 2014 The development of co-representation effects in a joint task: do children represent a co-actor? *Cognition* **132**, 269–279. (doi:10.1016/j.cognition.2014.04.008)
9. Brownell CA. 2011 Early developments in joint action. *Rev. Phil. Psychol.* **2**, 193–211. (doi:10.1007/s13164-011-0056-1)
10. Gilbert M. 2017 Joint commitment. In *The Routledge handbook of collective intentionality* (eds M Janovic, L Ludwig), pp. 130–139. New York, NY: Routledge.
11. Bangerter A, Genty E, Heesen R, Rossano F, Zuberbühler K. 2022 Every product needs a process: unpacking joint commitment as a process across species. *Phil. Trans. R. Soc. B* **377**, 20210095. (doi:10.1098/rstb.2021.0095)
12. Heesen R *et al.* 2021 Assessing joint commitment as a process in great apes. *Iscience* **24**, 102872. (doi:10.1016/j.isci.2021.102872)
13. Brown P, Levinson SC. 1987 *Politeness: some universals in language usage*. Cambridge, UK: Cambridge University Press.
14. Tomasello M. 1995 Joint attention as social cognition. In *Joint attention: its origins and role in development* (eds C Moore, PJ Dunham), pp. 103–130. Hillsdale, NJ: Lawrence Erlbaum.
15. Warneken F, Chen F, Tomasello M. 2006 Cooperative activities in young children and chimpanzees. *Child*

Dev. **77**, 640–663. (doi:10.1111/j.1467-8624.2006.00895.x)

16. Grafenhain M, Behne T, Carpenter M, Tomasello M. 2009 Young children's understanding of joint commitments. *Dev. Psychol.* **45**, 1430–1443. (doi:10.1037/a0016122)
17. Grafenhain M, Carpenter M, Tomasello M. 2013 Three-year-olds' understanding of the consequences of joint commitments. *PLoS ONE* **8**, e73039. (doi:10.1371/journal.pone.0073039)
18. Hamann K, Warneken F, Tomasello M. 2012 Children's developing commitments to joint goals. *Child Dev.* **83**, 137–145. (doi:10.1111/j.1467-8624.2011.01695.x)
19. Kachel U, Svetlova M, Tomasello M. 2018 Three-year-olds' reactions to a partner's failure to perform her role in a joint commitment. *Child Dev.* **89**, 1691–1703. (doi:10.1111/cdev.12816)
20. Kachel U, Svetlova M, Tomasello M. 2019 Three-and 5-year-old children's understanding of how to dissolve a joint commitment. *J. Exp. Child Psychol.* **184**, 34–47. (doi:10.1016/j.jecp.2019.03.008)
21. Warneken F, Gräfenhain M, Tomasello M. 2012 Collaborative partner or social tool? New evidence for young children's understanding of joint intentions in collaborative activities. *Dev. Sci.* **15**, 54–61. (doi:10.1111/j.1467-7687.2011.01107.x)
22. Hunnius S, Bekkering H, Cillessen AH. 2009 The association between intention understanding and peer cooperation in toddlers. *Int. J. Dev. Sci.* **3**, 368–388. (doi:10.3233/DEV-2009-3404)
23. Warneken F, Steinwender J, Hamann K, Tomasello M. 2014 Young children's planning in a collaborative problem-solving task. *Cogn. Dev.* **31**, 48–58. (doi:10.1016/j.cogdev.2014.02.003)
24. Rakoczy H, Warneken F, Tomasello M. 2008 The sources of normativity: young children's awareness of the normative structure of games. *Dev. Psychol.* **44**, 875. (doi:10.1037/0012-1649.44.3.875)
25. Rakoczy H, Schmidt MF. 2013 The early ontogeny of social norms. *Child Dev. Perspect.* **7**, 17–21. (doi:10.1111/cdep.12010)
26. Rossano F, Rakoczy H, Tomasello M. 2011 Young children's understanding of violations of property rights. *Cognition* **121**, 219–227. (doi:10.1016/j.cognition.2011.06.007)
27. Keupp S, Behne T, Rakoczy H. 2013 Why do children overimitate? Normativity is crucial. *J. Exp. Child Psychol.* **116**, 392–406. (doi:10.1016/j.jecp.2013.07.002)
28. Brownell CA, Brown E. 1992 Peers and play in infants and toddlers. In *Handbook of social development* (eds VB Van Hasselt, M Hersen), pp. 183–200. Berlin, Germany: Springer.
29. Ross HS, Lollis SP. 1987 Communication within infant social games. *Dev. Psychol.* **23**, 241. (doi:10.1037/0012-1649.23.2.241)
30. Eckerman CO, Davis CC, Didow SM. 1989 Toddlers' emerging ways of achieving social coordinations with a peer. *Child Dev.* **60**, 440–453. (doi:10.2307/1130988)
31. Hartup WW, Laursen B, Stewart MI, Eastenson A. 1988 Conflict and the friendship relations of young children. *Child Dev.* **59**, 1590–1600. (doi:10.2307/1130673)
32. Rende RD, Killen M. 1992 Social interactional antecedents of conflict in young children. *Early Childhood Res. Q.* **7**, 551–563. (doi:10.1016/0885-2006(92)90086-E)
33. Hinde RA, Titmus G, Easton D, Tamplin A. 1985 Incidence of 'friendship' and behavior toward strong associates versus nonassociates in preschoolers. *Child Dev.* **56**, 234–245. (doi:10.2307/1130190)
34. Howes C, Matheson CC. 1992 Sequences in the development of competent play with peers: social and social pretend play. *Dev. Psychol.* **28**, 961. (doi:10.1037/0012-1649.28.5.961)
35. Bakeman R, Adamson LB. 1984 Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Dev.* **55**, 1278–1289. (doi:10.2307/1129997)
36. Hay DF, Caplan M, Nash A. 2018 The beginnings of peer relations. In *Handbook of peer interactions, relationships, and groups*, pp. 200–221. New York, NY: The Guilford Press.
37. Altmann J. 1974 Observational study of behavior: sampling methods. *Behavior* **49**, 227–266. (doi:10.1163/156853974X00534)
38. Rubin KH, Watson KS, Jambor TW. 1978 Free-play behaviors in preschool and kindergarten children. *Child Dev.* **49**, 534–536. (doi:10.2307/1128725)
39. Lillard A, Pinkham AM, Smith E. 2011 Pretend play and cognitive development. In *The Wiley-Blackwell handbook of childhood cognitive development* (ed. BU Goswami), pp. 285–311. New York, NY: Wiley.
40. Shantz CU, Shantz DW. 1985 Conflict between children: social-cognitive and sociometric correlates. *New Directions Child Dev.* **1985**, 3–21.
41. Dawe HC. 1934 An analysis of two hundred quarrels of preschool children. *Child Dev.* **5**, 139–157. (doi:10.2307/1125449)
42. Hay DF, Ross HS. 1982 The social nature of early conflict. *Child Dev.* **53**, 105–113. (doi:10.2307/1129642)
43. Jersild AT, Markey FV. 1935 Conflicts between preschool children. *Child Dev.* **21**, ix+181.
44. Dunn J, Herrera C. 1997 Conflict resolution with friends, siblings, and mothers: a developmental perspective. *Aggressive Behav.* **23**, 343–357. (doi:10.1002/(SICI)1098-2337(1997)23:5<343::AID-AB4>3.0.CO;2-J)
45. Killen M, Turiel E. 1991 Conflict resolution in preschool social interactions. *Early Educ. Dev.* **2**, 240–255. (doi:10.1207/s15566935eed0203_6)
46. Shantz CU. 1987 Conflicts between children. *Child Dev.* **58**, 283–305. (doi:10.2307/1130507)
47. Corsaro WA, Eder D. 1990 Children's peer cultures. *Annu. Rev. Sociol.* **16**, 197–220. (doi:10.1146/annurev.so.16.080190.001213)
48. O'Brien M, Roy C, Jacobs A, Macaluso M, Peyton V. 1999 Conflict in the dyadic play of 3-year-old children. *Early Educ. Dev.* **10**, 289–313. (doi:10.1207/s15566935eed1003_4)
49. Vespo JE, Pedersen J, Hay DF. 1995 Young children's conflicts with peers and siblings: gender effects. *Child Study J.* **25**, 189–212.
50. ELAN (Version 6.3) (Computer software). 2022 Nijmegen: Max Planck Institute for Psycholinguistics, The Language Archive. See https://archive.mpi.nl/tla/elan.
51. Byrne RW, Cartmill E, Genty E, Graham KE, Hobaiter C, Tanner J. 2017 Great ape gestures: intentional communication with a rich set of innate signals. *Anim. Cogn.* **20**, 755–769. (doi:10.1007/s10071-017-1096-4)
52. Hinde RA. 1976 On describing relationships. *J. Child Psychol. Psychiat* **17**, 1–19.
53. Hill KR, Wood BM, Baggio J, Hurtado AM, Boyd RT. 2014 Hunter-gatherer inter-band interaction rates: implications for cumulative culture. *PLoS ONE* **9**, e102806. (doi:10.1371/journal.pone.0102806)
54. Hay DF. 1984 Social conflict in early childhood. *Ann. Child Dev.* **1**, 1–44.
55. Houseman JA. 1972 An ecological study of interpersonal conflicts among preschool children. PhD thesis, Wayne State University, Detroit, MI, USA.
56. Kaufhold SP, Rossano F. 2020 Proximate mechanisms and relational history: the interdependence of food transfers in socially housed orang-utans (*Pongo abelii*). *Anim. Behav.* **167**, 243–253. (doi:10.1016/j.anbehav.2020.07.016)
57. Rossano F, Liebal K. 2014 'Requests' and 'offers' in orangutans and human infants. In *Requesting in social interaction* (eds P Drew, E Couper-Kuhlen), pp. 333–362. Amsterdam: John Benjamins.
58. Schegloff EA, Sacks H. 1973 Opening up closings. *Semiotics* **8**, 289–327.
59. Rossano F, Terwilliger J, Bangerter A, Getty E, Heesen R, Zuberbühler K. 2022 Data from: How 2- and 4-year-old children coordinate social interactions with peers. Dryad Digital Repository. (doi:10.5061/dryad.dr7sqvb0z)
60. Rossano F, Terwilliger J, Bangerter A, Genty E, Heesen R, Zuberbühler K. 2022 How 2- and 4-year-old children coordinate social interactions with peers. FigShare. (doi:10.6084/m9.figshare.c.6039064)