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Dyadic interactions during infant learning: Exploring infant-parent exchanges in experimental eye-tracking studies

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A B S T R A C T

The role of parental behaviour in modulating infant learning during experimental studies has been rarely explored. Yet, multiple strands of research suggest that dyadic infant-parent interactions could be as important for infant learning and regulation during experimental studies with infants, as they are during their free, unconstrained play. Recently, we have developed a coding scheme for analysing the quantity and quality of various extraneous behaviours of both the parent and the infant during standard eye-tracking experiments. Here, we present a quantitative analysis of selected parental behaviours and their role in modulating infant task performance. We analysed whether parental looking (at the screen or at the infant), talking and pointing and physical contact change with the task that the infant is performing. The results showed subtle, systematic adjustments of parental behaviours in relation to the task. Moreover, parental behaviours were related to infant performance for tasks that involve learning (habituation task) and free viewing of visual stimuli, but not for those involving simple orienting responses (gap-overlap task). Additional dynamic analyses using Cross-Recurrence Quantification Analysis indicated that parents were closely following the infants' shifts, looking toward and away from the screen. Altogether, these results indicate that infant performance in eye-tracking tasks are associated with subtle adjustments of parental behaviours. This may suggest that early on infants perform learning tasks in coordination with parental behaviour as a dyadic unit of learning.

1. Introduction

Humans engage in social interactions from birth and these daily social exchanges with caregivers, other adults and children are fundamental for shaping their learning experience over the first years of life. Thanks to several attention biases newborns are prepared for attending and preferential processing of social stimuli, such as faces, eye gaze, or speech (Johnson et al., 1991; Farroni et al., 2002; Vouloumanos & Werker, 2007). Within the first months of life infants are not only attending to social signals, but also actively engaging in dyadic social interactions. Already at 2 months of age they are sensitive to the basic structure of interactions in terms of turn-taking or contingent responding (Murray & Trevarthen, 1985; Nadel, Carchon, Kervella, Marcelli, & Réserbat-Plantey, 1999) and subsequently, undertake attempts to repair interactive sequences when they are disrupted (Tronick & Gianino, 1986). Finally, even 2-month-olds are aware of being an object of another person's attention (Reddy, 2003) while 4-month-olds search for the localisation

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of voice in interactive social situations (Kezuka et al., 2017).

This surprisingly early preparedness for social interactions has significant consequences for the dynamics of learning in the first year of life. As they engage in visual exploration or play with new objects, the large amount of such activity takes place in the context of dyadic exchanges (de Barbaro et al., 2013; Mason et al., 2019). It has been shown that social context and dyadic play in contrast to solo play can enhance sustained attention to objects (Wass et al., 2018). New learning experiences often form the content of early social interactions, creating opportunities for sharing objects of attention and speaking about them (Abney, Suanda, Smith, & Yu, 2020; West & Iverson, 2017). Moreover, social interactions may drive cognitive development, as their quality is related to the developmental timing of cognitive milestones (Elsabbagh et al., 2013; Karmiloff-Smith et al., 2010). Yet, with respect to experimental studies of infant learning researchers have paid relatively little attention to these dyadic interactive aspects of infants' cognitive activity. Experimental studies commonly focused on conceiving the infant as an independent learner building own mental representations. This notion has lead to treating parent in experimental tasks as a source of confounding behaviours that need to be controlled with strict task instructions. This standard practice stands in stark contrast to research showing parental contributions to infant and toddler learning (e.g. Reddy, 2008, p. 26; McQuillan et al., 2020).

The independent learner view of the developing infant is challenged by several important observations on early infant development. Young infants depend on their parents for regulation of the state and emotions, a phenomenon documented in research on infant-parent co-regulation (Feldman, 2003; Reddy et al., 1997). Infant learning in different contexts and situations, especially in play is structured by the parent through various scaffolding behaviours (Tamis-LeMonda & Bornstein, 1989; Yu & Smith, 2016). Finally, cognition is embodied and the rapid growth of infants' bodies place changing constraints on their learning activities (Rachwani et al., 2020; Soska & Adolph, 2014; Jarvis et al., 2020). Parental activity is important for monitoring those constraints and facilitating learning despite them. Taken together, there is strong evidence to suggest that even under standard experimental conditions with screen presentation of stimuli, infants are engaged in ongoing dyadic social exchanges with the caregiver, who scaffolds their learning, co-regulates their state and alleviates bodily constraints on visual exploration and learning.

In this study we investigated spontaneous dyadic, interactive behaviours of the parent and the infant while the latter was engaged in performing experimental eye-tracking tasks. Already at the age of 5 months infants show rapid improvements in endogenous control of their looking (for a review see Hendry et al., 2019). On the other hand, even in the preceding months of life they are aware of being an object of attention (Reddy, 2003) and seek social interaction partners when exploring the environment (Kezuka et al., 2017). They also benefit from parental scaffolding in learning situations (Hilbrink, Gattis, & Levinson, 2015; Landry, Garner, Swank, & Baldwin, 1996; Niedźwiecka, Ramotowska, & Tomalski, 2018). Other aspects of infant-parent interaction, such as affective touch, also modulate learning and attention of 4-month-olds (Della Longa et al., 2019). Altogether, there is ample evidence that dyadic exchanges of parents and their 5- and 6-month-old infants are likely modulating infants' experimental task performance in standard learning tasks, even prior to the onset of triadic attention in social interactions (for a review see Abney et al., 2020). For these reasons we have focused on the role of dyadic exchanges of infants aged 5 and 6 months of age, at the onset of their independent attention control skills.

More specifically, we tested 1) whether parental behaviors in infant tasks will involve sensitivity to the changing demands of different tasks their infants are facing and 2) whether parental spontaneous behaviours are related to their infants' task performance. To this end we used a previously developed manual coding scheme for analysing video recordings of infant and parent behaviour during eye-tracking tasks (IP-BET, Tomalski & Malinowska-Korczak, 2020). We re-analysed an existing dataset by measuring eye-tracking task differences in parental looking behaviour, talking and pointing to the screen, as well as in active physical contact maintained by the dyad. We used three different tasks that differed significantly in their complexity and demands (simple orienting task, infant-controlled habituation with simple and complex visual stimuli and freeviewing of dynamic and static stimuli. Finally, we conducted exploratory analysis of the dynamics of infant and parent looking at the stimulus presentation screen and away from it with Cross-Recurrence Quantification Analysis (CRQA) to understand the coupling of their looking throughout the eye-tracking session (see Supporting Information).

2. Methods

2.1. Participants

A total of 120 infants were enrolled in a longitudinal study of attention and cognitive development. Here we present data from the first visit at the age of 5–6 months (M age = 165.67 days, range 134 – 200). All participants had normal birthweight (>2500 g), were healthy and delivered at term (36 – 42 weeks gestational age). Participants were excluded from analyses due to: fussiness (n = 3), calibration problems or eye-tracking equipment error (n = 15), or missing/low quality video recording of the infant behaviour (n = 8) or the parent behaviour (n = 19). The final sample consisted of 75 healthy infants (38 girls) at the age of 134–189 days (M = 166.20; SD = 12.81). Mean maternal age at infant birth was 30.43 years, (SD = 3.98, range 23–39). The sample consisted of predominantly middle-class families from a city with > 1.5 mln inhabitants. Maternal education was on average M = 17.30 of completed years (SD=1.93, range 11–24). The participants included in the analyses did not significantly differ from those that were excluded in terms of infant's age, gestational age, birthweight, maternal age, maternal education (all *t*s < 0.98, all *p*s > 0.33). The study was approved by the local institutional ethics committee. All parents gave written informed consent before testing and received a small gift (baby book) and a certificate of attendance.

2.2. Procedure

After a brief warm-up time in the babylab testing room, infants were seated in a high chair (n = 7) or on a parent's lap (n = 68) approximately 60 cm from the monitor. The seating was decided by the parent at the beginning of the session. If an infant was seated in a high chair (with additional padding to make it suitable for this age group), the parent sat in a chair positioned to the left and just behind the high chair in order to touch and soothe the infant, if necessary. As previous analysis did not show significant differences in parent behaviour depending on the infant seating, all analyses were carried out on participants collapsed across the two positions (see Tomalski & Malinowska-Korczak, 2020).

Eye-tracking data were collected on a Tobii T60XL eye-tracker (Tobii Inc.) with a 24′' monitor, 60 Hz sampling rate and 0.5° accuracy (value provided by the manufacturer). The five-point infant-friendly calibration was applied. Experimental tasks were presented after the infant successfully calibrated at least 4 points. Infants performed 4 blocks of each of three gaze-contingent tasks (gap-and-overlap, habituation and free viewing, see below). The blocks of the tasks were interweaved and presented in two pseudorandom orders, counterbalanced between participants. The duration of the entire eye-tracking session (including calibration) did not exceed 10 min. Task presentation was controlled with a 13" MacBook Pro in Matlab with Psychophysics Toolbox (Kleiner et al., 2007) and Talk2Tobii package (Deligianni et al., 2011) for eye-tracking data acquisition.

Infant and parent behaviour was recorded by a remote-controlled CCTV camera (SD image quality) and a microphone placed on a wall approximately one meter above the stimulus monitor (slightly to the left). Except for the monitor and camera lens, the entire area around the eye-tracker monitor was covered with a black cloth to provide a uniform background. The camera view was set to record the entire body of an infant together with a view of at least the upper part of the parent's body. The recording started when the first task began and lasted until the session was terminated. The presentation of eye-tracking stimuli for each participant in each task was recorded simultaneously with the camera view of the participants for later coding using ScreenFlow 5 (Telestream, Inc.).

Parents were given standard eye-tracking task instructions, developed within a consortium of infancy laboratories (Jones et al., 2019), i.e. not to talk or interfere with infant looking and behaviour, to maintain infant in a stable and upright position at constant distance from the screen (for full instructions see Supporting Information).

2.3. Eye-tracking tasks

We chose three tasks that are well-established in the infancy literature and produce robust experimental effects in infants at 5–6 months of age, as well as represent a variety of visual behaviours observable in this age group (rapid orienting, visual habituation to stimuli of varying complexity and free scanning of stimuli in the visual field).

2.3.1. Gap-overlap task

Gap-overlap task involved making rapid saccades from the central stimulus to a peripheral target, with multiple trials being presented in a single block. Each trial was initiated only when the infant fixated the central stimulus, thus the infant's looking at the screen was maintained throughout the entire block.

We used the gap-overlap task (Farroni, Simion, Umiltà, & Dalla Barba, 1999) in a version prepared by Wass and colleagues (Wass, Porayska-Pomsta, & Johnson, 2011). The task consisted of at least 48 trials (divided into 4 blocks). An additional block was run until enough usable trials were collected (12 per condition), or 80 trials had been presented, or the infant became inattentive. Each trial began with a central target (CT, a cartoon clock, subtending 4.5° visual angle in diameter) appearing after a variable inter-stimulus interval. Once the CT was fixated by the participant, a lateral target (LT, a cartoon cloud, subtending 3° in diameter) was presented on either side of the screen 13° away from the centre. There were three trial types, presented in equal number in random order: Gap – LT appeared 200 ms from the CT offset, Baseline – LT appeared as soon as CT disappeared from the screen, Overlap – CT remained on the screen for 200 ms from the onset of LT.

In the subsequent analyses regarding infants' performance we used average saccadic reaction times (SRT) measured as the latency between LT appearance and the reported position of gaze leaving the central fixation area (a 9° box around the CT) for the gap and overlap condition. SRTs lower than 100 and greater than 2000 ms were excluded.

2.3.2. Habituation task

An infant-controlled habituation task (Courage et al., 2006) was administered to measure infant look durations in response to repeated stimuli. The same stimulus was repeatedly presented until a reduction in looking was achieved. A version developed by Wass and colleagues was used (Wass, Porayska-Pomsta, & Johnson, 2011; Wass & Smith, 2014). The task consisted of four different still images presented in a randomised order. In a simple, unattractive stimulus condition two simple geometric shapes (a diamond and a cross on a uniform background), which may have been mildly frustrating were presented. In a complex stimulus condition two attractive complex scenes (multiple flowers or fish), were presented. These stimuli, although more engaging, were more difficult to process visually and led to longer habituation times (Wass & Smith, 2014; Tomalski et al., 2017).

The difference in complexity of these stimuli was previously confirmed (Wass & Smith, 2014) by a feature congestion analysis, which measured the level of visual clutter (see Rosenholtz et al., 2007). Within each block the infant fixated the central stimulus, which initiated the presentation of the habituation stimulus until the participant looked away from the screen, only to be re-directed to the screen again by the next central stimulus or until a habituation criterion was reached. As a result, the habituation task produced sequences, where the infant was repeatedly looking at the screen and then away from it. We used average peak look duration (in seconds) for simple and complex stimuli, as an index of infant performance in this task. Peak look durations were log-transformed to correct their skewed distributions.

2.3.3. The free viewing task

This task (Wass & Smith, 2014) measured spontaneous eye movements during unconstrained viewing of presented images and short clips. The stimuli consisted of four images (static stimuli) and four videos (dynamic stimuli). Images depicted 2 social scenes with multiple faces and human figures and 2 non-social scenes with multiple colourful objects, e.g. flowers, easter eggs. Each picture lasted 10 s. Similarly, 4 videos represented 2 social clips with portrait view of the human figure saying baby rhymes and 2 non-social cartoon videos with a toy object, a plane or vehicle moving around the screen). Each video lasted 30 s. The task permitted looking away from the screen if the infant lost interest or became distracted. For statistical analyses in this paper we calculated total fixation durations for each of the presented stimuli and averaged it within the given category (e.g., dynamic social stimuli).

Fixation coordinates and durations were extracted using a novel noise-robust fixation detection algorithm that uses 2-means clustering (Hessels et al., 2016). We used most of the suggested default settings for the algorithm. Particularly, we used a Steffen interpolation with an interpolation window of 100 ms and an interpolation edge of 2 samples (i.e. 33.33 ms), a clustering window size of 200 ms, downsampling to assure that the transitions between fixations are not caused by high-frequency noise in the data at 30, 20 and 15 Hz and a clustering cutoff of 2 times the standard deviation above the k-means weights. Next, all those fixations that had a minimum duration of 100 ms were considered valid and shorter fixations candidates were excluded. Finally, we merged fixation candidates that were less than 0.7 degrees apart and separated by less than 30 ms (for in-depth description of the parameters see Hessels et al., 2016).

2.4. Infant-parent behaviour during eye-tracking (IP-BET) coding scheme

The theoretical background and rationale for coding scheme categories together with reliability data have been presented elsewhere (Tomalski & Malinowska-Korczak, 2020). In the current study we used an existing dataset, but re-analysed it by calculating the duration and frequency of selected categories from IP-BET separately for each of the three eye-tracking tasks.

In the following analyses, we employed selected categories from IP-BET. Regarding parental behaviour, categories included looking behaviour (at the screen, at the infant) expressed as a proportion of time (percentage of the total observation time) or mean duration of looking episode (in seconds). Other parental categories such as pointing at the screen and talking to the infant, which were coded as individual instances (without duration) were expressed as a rate per minute (mean number of episodes per minute of the observation). We used one more category specified for dyad level - physical contact. It was defined as an active physical contact between parent and infant (parent hugging the infant, infant and parent holding hands). This variable was considered a dyadic measure, as touch was actively maintained by both interactive partners and it could have been initiated by either of them. It was expressed as a percentage of

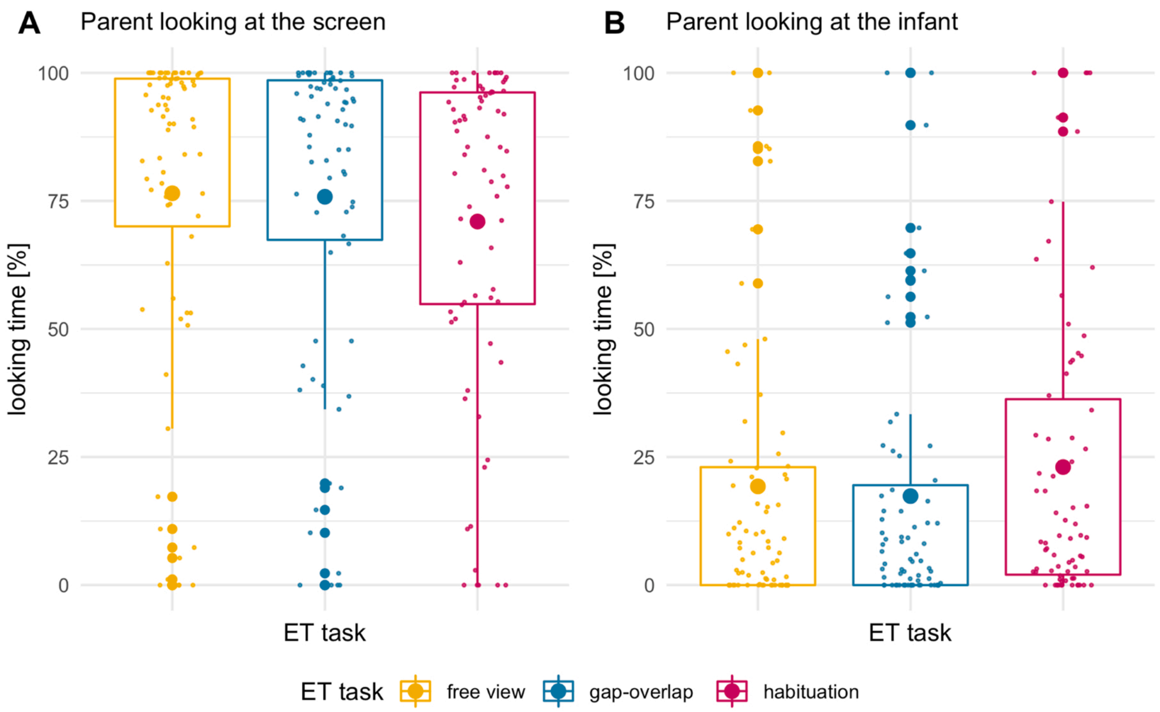

Fig. 1. Boxplots with individual data values representing the total duration of parental looking at the screen (A) and at the infant (B), in the freeview, gap-overlap and habituation tasks as proportion of the total time of corresponding task.

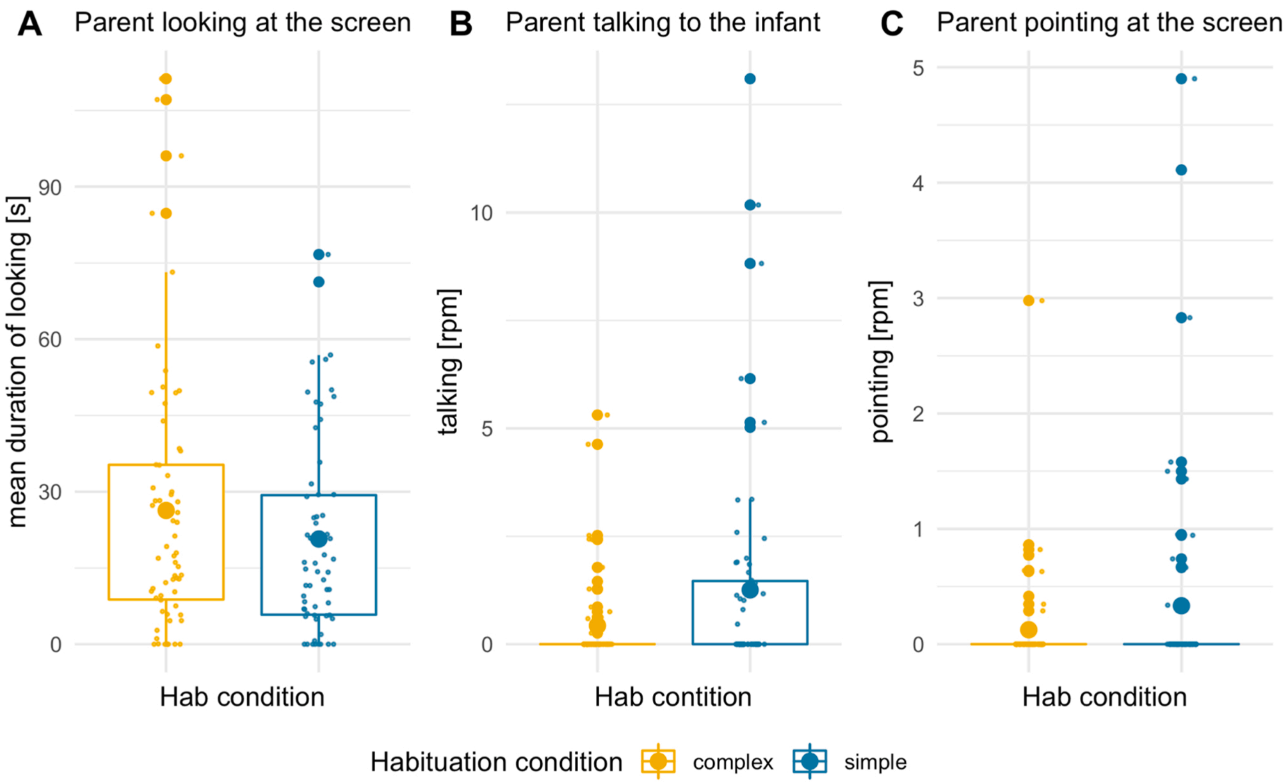

Fig. 2. Boxplots with individual data values representing the mean duration of a parental look at the screen (A), the rate of parental utterances (B) and pointing per minute (C) in the simple and complex conditions of the habituation task.

total duration or rate per minute. Measures of participants behaviours were calculated for specific eye-tracking tasks.

2.5. Analysis plan

Eye-tracking data that was recorded during the experimental session was stored for pre-processing and analysis offline. Video-recordings from another angle camera for IP-BET coding were also stored and manually coded offline. Eye-tracking and behavioural coding scheme metrics were calculated and analysed together for each infant-parent dyad analysed in the paper.

Firstly, we analysed mean differences in (i) parental looking, pointing, talking and (ii) dyadic physical contact between three eye-tracking tasks – gap-overlap, habituation and freeview. Within the habituation task, we also compared parental behaviours between simple and complex stimulus conditions. Due to lack of normal distribution, between-task differences in parental behaviours were analysed using repeated-measures Friedman ANOVA. Follow-up pairwise comparisons were conducted with Wilcoxon signed-rank tests (reported *p*-values were Bonferroni-corrected for multiple comparisons).

Secondly, we tested the relation between infant performance in eye-tracking tasks with parental looking behaviour using Spearman correlations. In the case of parental pointing, talking and dyadic physical contact we tested whether the presence or absence of these behaviours related to the infants' performance with t-tests. This solution was chosen because of an overall low frequency of these behaviours.

3. Results

3.1. Task differences in parental looking

First, we investigated whether parents adjusted their looking behaviour to the infant's experimental task demands. We predicted that more engaging tasks would result in the parents looking longer at the screen (gap and freeview) than in the habituation task, which requires the infants to repeatedly looking away from the screen. Our results confirmed this prediction, ($\chi^2(2) = 13.66$, $p = .001$, see Fig. 1A). Looking at the screen in the habituation task was significantly shorter than in the gap or freeview tasks ($p = .043$ and $p =$ .002*,* respectively). Meanwhile, during the gap and freeview tasks their looking at the screen remained consistently higher and very similar ($p = .51$).

In line with lower attention to the screen, during the habituation task parents looked more at their infant than during the freeview tasks ($\chi^2(2) = 9.48$, $p = .009$, see Fig. 1B, pairwise comparisons: hab > freeview, $p = .034$; hab ~ gap, $p = .054$). In the gap and freeview task, parental looking at infant was comparable between these two and lower than in the habituation task ($p = .99$). We also analysed the duration of looking away from the screen and not at the infant by parents, but median value across all tasks was equal to

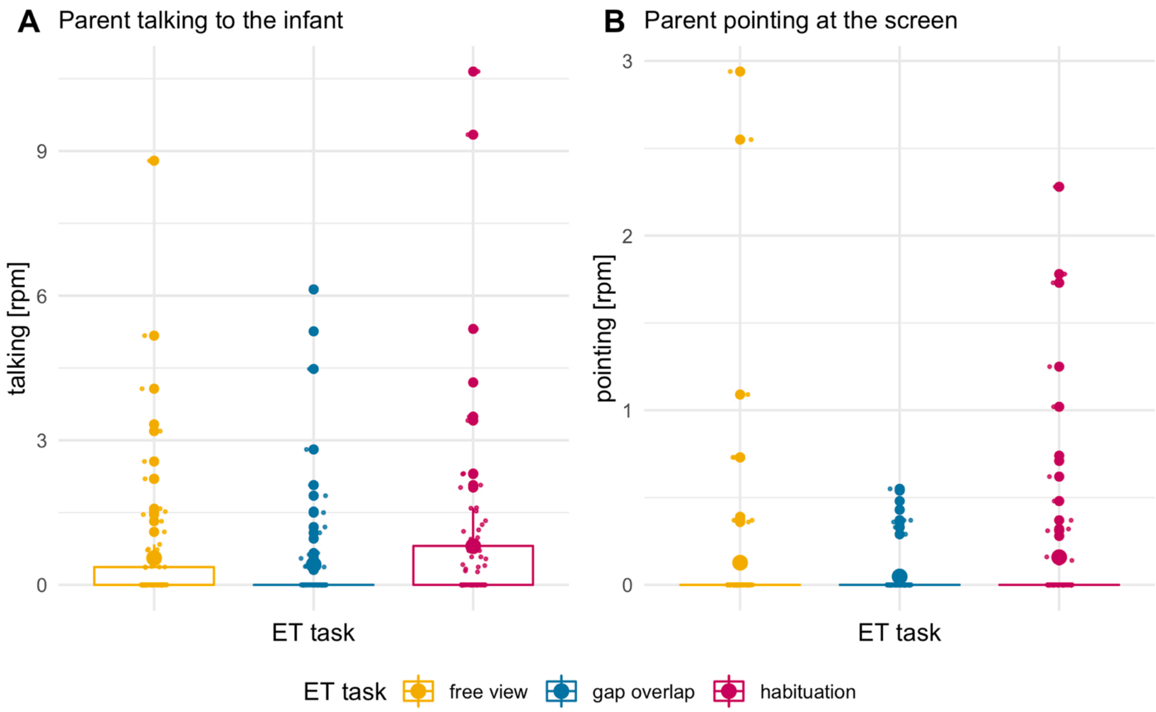

Fig. 3. Boxplots with individual data values representing the rate per minute of episodes of talking to the infant (A) and pointing to the screen (B) in the freeview, gap-overlap and habituation tasks.

zero with only a few parents looking consistently away from the screen for longer periods of time.

3.1.1. Parental looking, talking and pointing - habituation task conditions

Next, we tested the same hypothesis about parental looking being modulated by task demands but this time by comparing two conditions of the habituation task: with simple and complex stimuli. This analysis was carried out on a subset of infants, where we could code individual blocks of the task (n = 62). The analysis of the total duration of looking at the screen by the parent did not reveal any significant differences ($z = -0.73$, $p = .47$). However, if parents follow their infant's looking towards and away from the screen every time a stimulus is presented, then their individual looks should be on average longer in the complex than the simple condition. Indeed, we have found significantly longer mean duration of a look at the screen in the complex compared to simple condition ($z = -2.02$, $p = .022$, see Fig. 2A). We did not observe any significant differences in looking at the infant (either mean or total duration, both $zs < 0.67$, $ps > 0.50$).

We also investigated simple vs. complex condition differences in other parental activities (talking and pointing to the screen) that may indicate their monitoring of the infant state and attempts to increase their attention, especially during the less engaging condition with simple stimuli. Only a subset of parents exhibited these behaviours during this task. However, we found that parents significantly more often talked to the infant ($z = -3.11$, $p < .001$, see Fig. 2B) and pointed to the screen during the simple than the complex condition ($z = -1.81$, $p = .037$, see Fig. 2C).

3.2. Task differences in parental talking and pointing

We analysed task differences in other parental behaviours, such as talking to the infant to signal caregivers' presence, or pointing to the screen to bring back the infant's attention. Significant task differences were found for talking to the infant ($\chi^2(2) = 9.05$, $p = .011$, see Fig. 3A), but not for pointing to the screen ($\chi^2(2) = 3.98$, $p = .137$, see Fig. 3B). However, Bonferroni-corrected pairwise analyses did not confirm that the frequency of talking to the infant in the habituation was higher than gap task ($p = .14$) or the freeview task (hab~ fv, $p = .47$; gap ~ fv, $p = .99$).

3.3. Task differences in dyadic physical contact

Next, we measured the total duration of episodes of dyadic physical contact between the infant and the parent during each task (gap-overlap, habituation and freeview). As expected, the habituation task was associated with overall longer duration of active physical contact ($\chi^2(2) = 16.37$, $p < .001$, see Fig. 4A) than gap (hab > gap, $p = .001$) but not freeview task (hab ~ fv, $p = .238$). No difference between gap and freeview was found ($p = .19$). Episodes of dyadic physical contact were also more frequent in the

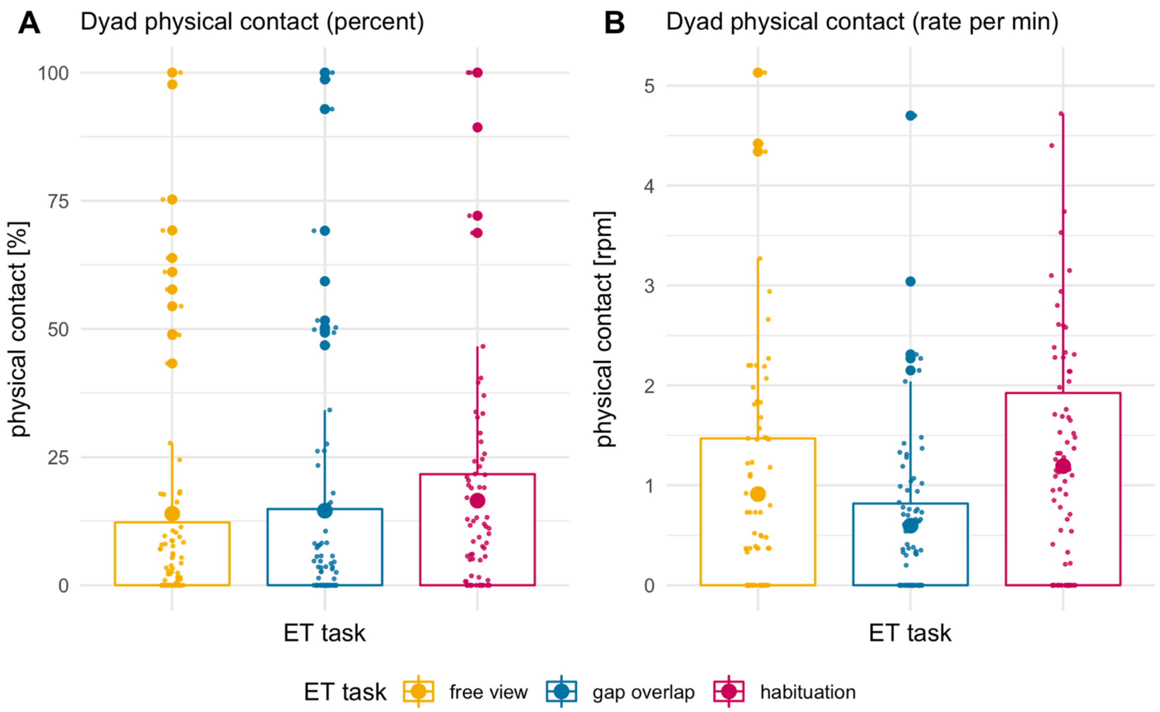

Fig. 4. Boxplots with individual data values representing the total duration as proportion of each task time (A) and frequency per minute (B) of episodes of dyadic physical contact in the freeview, gap-overlap and habituation tasks.

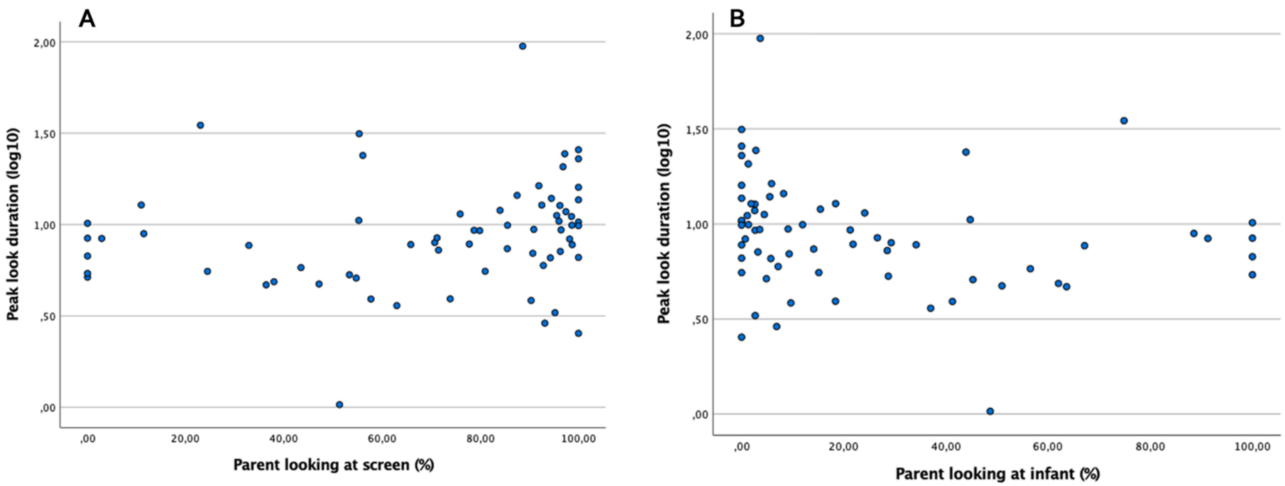

Fig. 5. Scatterplots presenting associations between infants' peak look duration in the simple condition of the habituation task with the total duration of parental looking at the screen (A) and total duration of parental looking at the infant (B) as proportion of the duration of habituation task.

habituation task than in other tasks ($\chi^2(2) = 19.65$, $p < .001$, see Fig. 4B), while their average duration did not differ between tasks ($\chi^2(2) = 2.66$, $p = .27$).

3.4. Associations of parental behaviours and dyadic physical contact with infant task performance

3.4.1. Gap-overlap task

These analyses included only participants with usable gap-overlap data (n = 58). First, we tested whether parental looking is associated with infant orienting speed in the task. We did not find any significant associations between the duration of parental looking at the screen, away from it, or at the infant with the infants' speed of orienting (all r_ss < 0.099, *ps* $> .45$) or attention disengagement (all r_ss < 0.12, *ps* $> .35$).

Infants, whose parents were talking to them during this task (n = 14) were on average slower to orient (M=0.32, SD=0.02) than those, whose parents did not talk to them (M=0.30, SD=0.02; $t = -2.63$, $p = .011$, d=0.81). There were no differences in attention disengagement between those groups ($t = -0.97$, $p = .34$).

The presence of dyadic physical contact during the gap-overlap tasks did not affect infants' latencies of saccadic responses in any of task conditions (all *ps* > 0.49).

3.4.2. Habituation task

These analyses included only participants with usable habituation task data combined with measures of parental behaviour from each task condition (simple vs complex stimuli, n = 68 available for this analysis). First, we tested whether the total duration of parental looking at the screen during this task was associated with the infants' performance in habituation. We found a significant, positive Spearman correlation in the simple stimulus condition ($r_s = 0.307$, $p = .011$, see Fig. 5A), but not in the complex condition ($r_s = -0.039$, $p = .74$).

Then, we tested whether the duration of parental looking at the infant was also associated with infants' task performance. A significant, but negative association was found for peak look duration in the simple ($r_s = -0.333$, $p = .006$, see Fig. 5B), but not for the complex condition ($r_s = -0.003$, $p = .98$).

Next, we compared peak look durations in the habituation task of infants, whose parent were pointing to the screen or talking to the infant and those whose parent did not. No group differences were found in either habituation task condition for talking (both *ts* < 0.68, *ps* > 0.51) or pointing (both *ts* < 0.33, *ps* $> .75$).

Finally, we analysed whether the presence of dyadic physical contact was related to infant habituation times. We found significantly shorter peak look in the simple condition for dyads, which maintained dyadic contact compared to those that did not ($t = 2.28$, $p = .026$, $d = 0.57$, see Fig. 6B). No such difference was found for the more difficult, complex condition of this task ($t = -0.62$, $p = .54$,

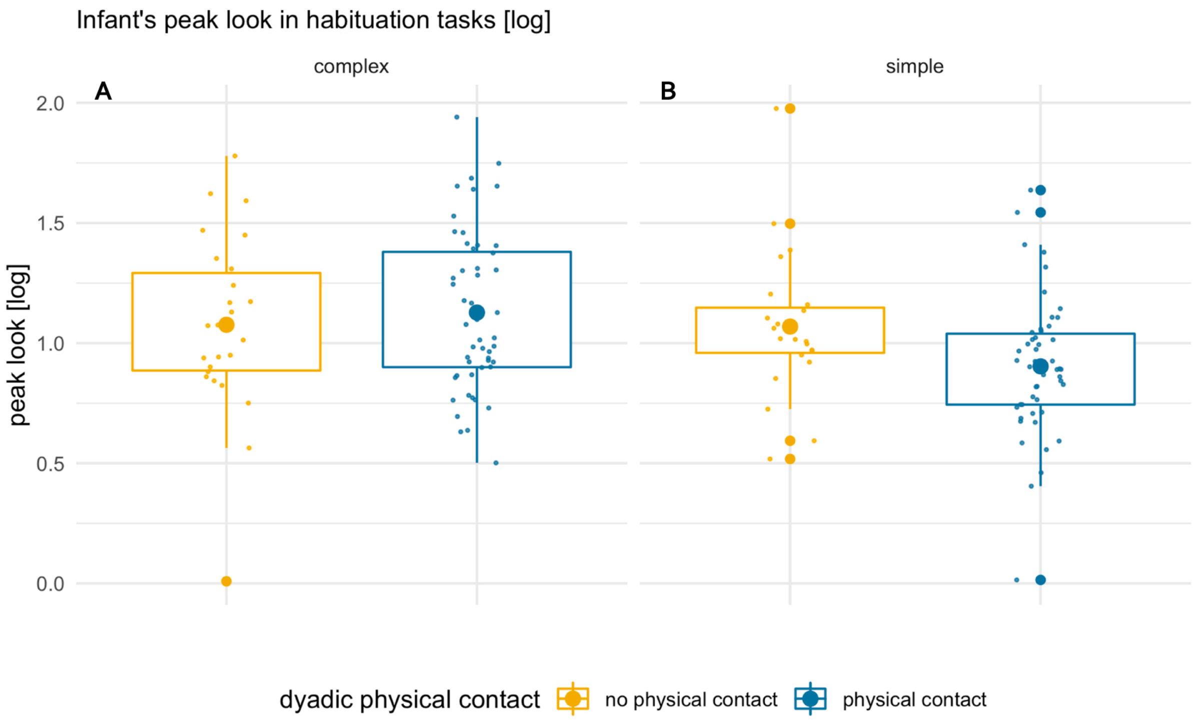

Fig. 6. Boxplots presenting peak look duration in the habituation task in the complex (A) and simple condition (B) with participants split by the presence of dyadic physical contact.

see Fig. 6A).

3.4.3. Freeview task

3.4.3.1. Parental looking and infant fixation durations on the stimuli. First, we investigated whether the total duration of parental looking at the screen was associated with the total duration of fixations made by the infant on stimuli in this task (n = 71 infants with eye-tracking data available). A weak, positive association was found for one condition - social static stimuli (r_s =0.237, p = .043). No significant correlations were found for other stimulus categories (all r_s < 0.2, all ps > .14).

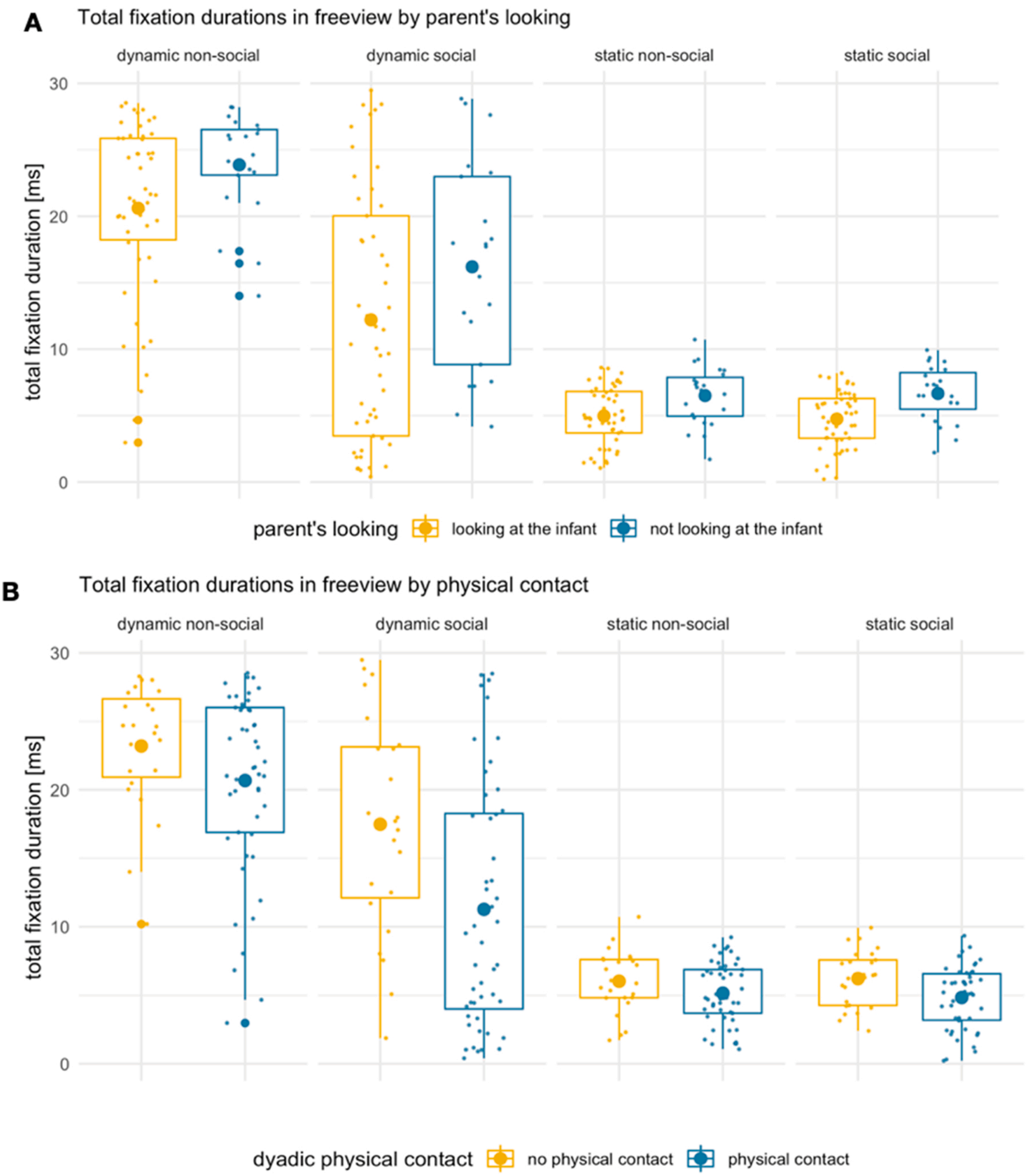

Fig. 7. Boxplots presenting mean total fixation duration in conditions of freeview task with participants split by the presence of parental looking at the infant (A) or the presence of dyadic physical contact in 2 types of dynamic and static stimuli (social and non-social) in the freeview task (B). Note that static stimuli were presented for 10 s, while dynamic for 30 s.

Next, we compared the infants' total duration of fixations on the stimuli between dyads where the parent was looking at the infant during this task, with those dyads, where the parent was only either looking at the screen or away from it, but not at the infant. The presence of parental looking was related to shorter total fixation time in most conditions (static social: $t = 3.56$, $p < .001$, $d = 0.90$; static non-social: $t = 2.68$, $p = .009$, $d = 0.68$; dynamic non-social: $t = 2.59$, $p = .012$, $d = 0.66$, see Fig. 7A), except for dynamic social stimuli ($t = 1.68$, $p = .098$).

3.4.3.2. Physical contact and infant fixation durations on the stimuli. We compared total fixation durations on the stimuli between dyads that maintained active physical contact during this task and those that did not. Significant group differences were found for most task conditions, with shorter total fixation durations being recorded for infants that maintained physical contact with their parent during the task (static social: $t = 2.43$, $p = .018$, $d = 0.60$; dynamic social: $t = 2.18$, $p = .035$, $d = 0.54$; dynamic non-social: $t = 2.80$, $p = .007$, $d = 0.71$, see Fig. 7B), except for static non-social stimuli, where no differences were found ($t = 1.44$, $p = .156$).

3.5. Supporting analyses of the dynamics of the infants' and parents' looking behaviour

In order to investigate whether there is any specific pattern of temporal contingencies in parental and infant looking at the screen, we have conducted additional dynamic analyses using the CrossRecurrence Quantification Analysis (CRQA). They are presented in the Supporting Information file. These analyses indicated that parents closely followed the point of view of their infant, such that they followed instances of infant looking away from the screen with their own looking away and sometimes also looking directly at the infant.

4. Discussion

The goal of our study was to investigate the social-interactive behaviours of the infant and the parent, while the 5- to 6-month-olds were performing screen-based experimental eye-tracking tasks. We manually coded multiple behaviours of each interactive partner using a previously developed scheme (IP-BET, Tomalski & Malinowska-Korczak, 2020) and analysed differences in behaviour between different tasks, but within each infant-parent dyad. Our second goal was to explore the associations between parental looking behaviour, talking and pointing to the screen, or dyadic physical contact and infant task performance.

Our results indicated within-parent differences in the object of attention, talking and pointing to the screen depending on the experimental task and its demands. We found that parents spontaneously adjusted their looking behaviour to the task the infant was performing at a given time. Parents were looking for a shorter time at the screen during the habituation task, which involved the infant repeatedly looking away from it, in comparison to gap and freeview tasks, which afforded longer continuous looking at the screen by the infant. At the same time, parents spent on average more time looking at the infant during the habituation than the freeview task. We also observed within-parent differences in the mean duration of one look at the screen between the simple and the complex condition of habituation task alone. As infants produced longer looks to complex stimuli their parents also produced longer looks at them in comparison to simple, less interesting stimuli. Altogether, a change in task demands was related to spontaneous adjustment of looking of the parent, who was not directly performing any task, but only accompanying the infant participant. Our results cannot be explained by task order or the infant becoming more tired towards the end of the session, as all tasks were separated into multiple blocks and presented in two pseudorandom sequences, counterbalanced across participants. Also, they cannot be attributed to differences in task duration, as we calculated the duration of all behaviours (e.g. looking) relative to the entire task duration (pooled all task blocks across the entire eye-tracking session).

Data on habituation task performance showed a moderate positive association between the duration of parental looking at the screen and the infants' peak look duration in the simple, less interesting condition. Conversely, greater parental looking at the infant was also related to lower peak look in this condition. If parental looking towards and away from the screen follows attention shifts of the infant, then the likely direction of these associations is that the parent is simply adjusting own looking (with a lag) in response to the infant's performance. The CRQA analysis and diagonal profiles confirm that parents are simply closely monitoring and following the shifts in focus of attention of their infants throughout the eye-tracking session (see Supporting Information). The sequences, where the infant is looking away from the screen and the parent is looking at him/her in the simple condition of habituation are more puzzling. One potential explanation of this effect is that the parent is monitoring the infant's state upon attention termination e.g. to respond to possible frustration and negative affect (hence an effect for looking at less engaging stimuli). Consistently with this result, we have found shorter total fixation durations in freeview task at both static and non-social dynamic stimuli in those infants, whose parents were looking at them during this task. It is also possible that caregivers, who were looking at their infant may have shown higher level of anxiety. Findings of a recent home-based study suggest that more anxious parents show higher physiological synchrony with their infants (Smith et al., 2021). An alternative explanation is that parents look at the infant in response to infants' calls or other communicative bids (in relation to stimuli). Unfortunately, we have not coded individual infant vocalisations to be able to test this hypothesis fully. The relationship between looking durations in visual attention tasks and communicative infant-parent bids requires further research. Earlier work has suggested that infant turning towards the parent could indicate successful learning even in 6-month-olds (Dunn & Bremner, 2017).

Next, we investigated parents' differential use of strategies for maintaining contact by talking to the infant and re-directing attention to the screen by pointing. Although these behaviours (each instance coded as a point event, so no duration data available) were supposedly minimised by explicit task instructions given to the parent, they appeared in a number of infant-parent dyads (see discussion in Tomalski & Malinowska-Korczak, 2020). We found an overall higher rate of talking to the infant during the habituation than the gap or freeview tasks, but no differences for pointing. Importantly, a comparison of two habituation conditions revealed significantly greater frequency of both talking and pointing during the less interesting simple condition relative to the complex condition. We interpret these findings as evidence for parental active involvement in monitoring the infant's state and attention distribution (Reddy et al., 1997) during eye-tracking tasks, especially in situations where the task may lead to frustration or fussiness. Notably, we did not observe any relations between talking and pointing and infant task performance.

We have also measured the dynamics of dyadic touch episodes. Unlike existing experimental infant studies on touch (e.g. Della Longa et al., 2019), we did not carefully control the type and timing of tactile stimulation. Instead, we opted for a naturalistic observation of spontaneously occurring episodes of dyadic physical contact. We found greater total duration and frequency of dyadic physical contact in the habituation task relative to gap and freeview tasks. This suggests that active touch could be selectively deployed by the dyad for specific tasks. Our data shows that infants, who maintained active physical contact with the parent were faster to habituate in the simple, less interesting condition, but not in the complex condition. Similarly, they also spent less time fixating the stimuli in the freeview task. We note that these effects appeared only in the condition with lower processing demands. It is likely that these episodes served multiple functions in this potentially frustrating task, as social touch plays a role in communication between the parent and the infant, facilitating infant learning (Della Longa et al., 2019; Pirazzoli et al., 2019) or regulating the infant's emotional state (e.g. Feldman et al., 1999).

We conclude by considering theoretical and methodological implications of these findings, particularly in the context of the second-person approach to psychological research (Reddy, 2008, pp. 26–28; Schilbach et al., 2013). It highlights the role of collective intentionality in social coordination and suggests that the "we" perspective (e.g. the infant-parent dyad) may predate in human development the emergence of the individual, "I" subjectivity (Brinck et al., 2017). Drawing on the second-person approach we emphasize the role of emotional engagement with the parent and of being aware of the parent's attention even prior to the onset of joint attention (see Reddy, 2008, pp. 32–42), when performing eye-tracking tasks in our study. We interpret our results as direct evidence that early learning situations, even in experimental settings, are likely inherently embedded within social-interactive dynamics of the infant and the parent (Suarez-Rivera et al., 2019; Yu & Smith, 2012). Such interpretation implies the need to include an additional level of analysis in experimental infancy research - apart from the individual infant performing a task "alone" – also the infant-parent dyad that takes part in the task jointly.

With respect to young infants, experimental looking tasks can be considered joint efforts of the infant-parent dyad, where it is difficult to clearly separate out the individual contributions of each interactive partner. In fact, we propose that the standard experimental situation in visual attention tasks could be conceived as a dyadic learning situation, rather than an individual, infant-only procedure. The primary consequence of such a point of view being that experimental studies on infant cognitive development by necessity do not study only the infant and that the social-interactive dynamics should be taken into account when designing and planning such studies. We propose that the inclusion of the dyadic level of analysis (e.g. by measuring the dynamics of infant-parent interactive behaviours) would significantly increase the ecological validity in experimental infancy research by getting closer to naturalistic learning settings. It may also help to increase the reliability of measurement in experimental tasks, which is a constant difficulty in infancy research (see e.g. Byers-Heinlein et al., 2021).

The second implication of our results is that in standard experimental procedures the parent should not be treated as a confounding agent, whose activity is to be minimised, monitored and controlled by verbal instructions. In conducting our study we have used the best available standard instructions for parents in order to minimise their activity (Jones et al., 2019). Our observational data, however, strongly suggest that parents not only take an active part in infant task performance, but their activity could be important for the infant's success in performing certain tasks. Furthermore, obtained results suggest that parental role goes far beyond mere support or scaffolding of learning situations so that the infant can deal with them alone. To the contrary, we propose that parental activity, when engaging in the task with the infant (e.g. through coordinated looking, response to communicative bids, establishing dyadic physical contact) could be necessary for achieving typical learning task performance and therefore, studies of infants within the first 6 months of life may benefit from considering the infant participant together with the caregiver as a dyadic unit of learning.

We note some limitations of our study, which could form the basis of future investigations. First, our analysis of infant-parent dyadic activity relied on coarse observational data. Thus, it was not possible to test in more detailed manner the dynamic sequences of specific parental behaviours and their causal relation to infant learning and attention distribution. Second, we have not coded the full, multi-modal extent of interactive social behaviour of the infant and our dynamic analyses could be extended to include a broader range of behaviours, which may complement each other in modulating infant attention and learning in this context. Thus, it is unknown, to what extent vocal interactions and looking behaviours on the parent's side (with potential regulatory function), are the effect of infant's active role in initiating such interactive exchanges. Third, some analyses relied on comparing dyads, where certain behaviours were present or absent. Experimental manipulations of the presence of certain behaviours are needed as a follow-up test of associations with task performance that were found. Finally, we measured a range of spontaneous dyadic behaviours that occurred within a very specific context of infant eye-tracking, where parental behaviour was limited by a set of instructions minimizing their involvement. In consequence, our results may not fully generalize to the broader range of situations of infant-parent screen-viewing or even to other experimental infant looking paradigms, with a different set and level of situational constraints. We highlight the need for further experimental studies, which directly manipulate the level of parental involvement, when the infant is performing specific visual tasks. This will help to better explain the extent to which the dyadic infant-parent exchanges are a critical factor ensuring 6-month-olds' task performance, or conversely, merely modulate some aspects of that performance.

In summary, our study shows that a regular eye-tracking experimental session with 5- to 6-month-olds is a situation of active, dyadic infant-parent interaction. Unusually for play situations in this age group, this dyadic activity was focussed on the infant's performance in specific cognitive tasks. Parents closely monitored the infant's shifts of focus of attention and reactively followed them throughout the entire session. In many dyads looking at the infant was present and related to infant performance in tasks involving free visual scanning of stimuli. Parental talking and pointing to the screen was also present and modulated by the task at hand. Finally, dyadic physical contact was maintained by the dyads in all tasks, with the greatest frequency and duration during the most frustrating task – habituation. This latter activity was also related to looking durations in two tasks involving looking at the stimuli.

Ethics statement

The studies involving human participants were reviewed and approved by the Departmental committee at the Faculty of Psychology, University of Warsaw, Poland. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

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CRediT authorship contribution statement

PT designed and planned the study, coordinated and oversaw the data collection, processed eye-tracking data for selected tasks, performed main statistical analyses, drafted the manuscript, edited and finalized the manuscript, secured funding. DLP processed eye-tracking data for selected tasks, conducted RQA analyses of data, consulted and contributed to the statistical analyses, contributed and edited the manuscript. AR contributed to the behavioural coding and oversaw reliability analyses, consulted and contributed to the statistical analyses, prepared figures, contributed and edited the manuscript. AM-K collected participant data, coordinated behavioural coding analysis, contributed to the manuscript draft.

Data Availability

The IP-BET coding data are available from the first author upon reasonable request via email.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.infbeh.2022.101780.

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