Infant Sex Effect on Naturally Occurring Attention Behaviors During Interactive Object Play

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***Abstract*— Visual attention plays a critical role in human learning, such as social, cognitive, and language development, though reported individual variation exists. Specifically, prevailing sex differences in attention behaviors have been documented throughout childhood and adulthood. However, we know relatively little about what experiences or processes through which individual differences, such as sex differences, may emerge and how parental behaviors may shape them. The present study captured infant and parent attention experiences within a social interactive play context to test the effect of infant sex. Results suggest that while male infants and their parents showed frequent attention shifts between regions of interest (e.g., hands, face, and objects) compared to the female infants and their parents, parents of female infants experienced longer attention to objects and parent-female dyads experienced longer moments of joint attention. These findings indicate the early emergence and rapidly changing characteristics of infant sex differences in visual attention and that parents may modify their attention behaviors to their infant's sex during play.**

Keywords—head-mounted eye-tracking, parent-infant interaction, infant sex, attention development, joint attention

I. Introduction

Visual attention is a critical component of early learning, including subsequent cognitive, language, and social-emotional growth [1], [2], [3], yet there has been reported individual variability in developmental trajectories and outcomes. Despite the importance of attention in learning and development, we know relatively little about the experiences and processes through which individual differences - such as sex differences - may emerge and how they may be shaped by parental behaviors. Head-mounted eye-tracking devices were used to capture both infant and parent moment-to-moment attention behaviors during a parent-infant object play session to document differences in attention experiences between parent-male and parent-female dyads.

A. Infant Attention Behaviors

Several infant sex differences have been reported in well-controlled experimental studies concerning attention allocation. A well-established line of research has documented visual preferences for sex-linked toys (e.g., female infants prefer to look at a doll over a toy truck) during the first 2 years of life [4], [5], [6]. 3-4-month-old and 9-10-month-old males demonstrate more fixations and attention shifts between internal and external facial features than females, who shift their attention between internal facial features more [7]. 12-month-old male infants prefer to look at non-social motion (e.g., racing cars) while female infants prefer to look at social motion (e.g., humans talking) [8]; similar results were found in neonates, with male neonates preferring to look at a physical-mechanical object while female neonates preferred to look at a face [9]. These social preferences have been elaborated on further, with 13-week-old and 12-month-old females demonstrating more eye contact [10], [11], 6-month-old females looking longer at faces [12], and 12-month-old females engaging in more reciprocal bidding sequences with their mothers [13]. However, some contradictory studies exist, with one finding no sex differences in neonatal eye contact [11] and a second finding a reversal in face-looking, in that 6-month-old males look longer at face [14]. Further research is still needed to identify the everyday experiences that might help us understand the inconsistencies in the magnitude and direction of these specific infant sex effects on attention capacities.

One attention experience that has been robustly linked to early learning including language and cognition [1], [2], [15] is joint attention (JA). JA refers to moments of socially coordinated attention-sharing between two individuals toward a specific target [3] and these experiences have been considered as two separate processes – the initiation of JA (IJA; an individual's ability to 'initiate' the direction of the gaze') and the response to JA (RJA; an individual's ability to 'follow' the direction of gaze). A study of toddlers from 17-36 months found females engaged in more frequent bouts of JA [16]. At 12 months, female infants had longer JA instances than males [13]. Female infants have also been documented to have more frequent IJA experiences at 9 months old [17] in addition to outperforming males on IJA and RJA measurements at 12 months old [18]. Yet other studies have found no effect of infant sex on JA experiences [19].

Consequently, we still know little about *how* these sex-based attention differences are shaped and if they prevail within social contexts with objective measurement. Parent-infant play has been proposed as an "early training ground" for the early development and learning of social attention behaviors [20] and therefore may provide insights into how and when visual attention begins to differentially develop between the sexes.

B. Parent Play Behaviors

The effect of infant sex on parental play behaviors has been well-established in the developmental literature. For example, mothers of 24-month-old females speak more and ask more questions [21]. In 6-, 9-, and 14-month-olds, mothers of females make more interpretations, engage in more conversation, and interact more while mothers of males make more comments and attentionals [22]. Parents of males use a higher proportion of explanations at 3, 9, and 24 months [23], [24] and talk more at 9 months [25]. Among 5-12-month-old infants, mothers of males use longer vocalizations, more words, and more affectionate terms than mothers of girls [26]. Mothers vocalize to, touch, and handle 6-month-

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old females more than mothers of males [27]. Parents of 6-month-old females tend to engage in more object play while parents of males use more physical contact [28].

However, these studies lack the exploration of parental *attention* behaviors as a function of infant sex. Infants as early as 2-5 days old have documented sensitivity to the attention of a social partner, including their eye contact and direction of gaze [29], [30], which may impact their social-communication development. Recent observational studies using head-mounted eye-tracking methods have successfully measured both infant and parent gaze patterns synchronously during parent-infant play, revealing parental attention behaviors that support infant sustained attention and JA, which have both been linked to language learning and cognitive development [20], [31], [32], [33]. If parents differ their attentional behaviors based on their infant's sex, this may therefore have consequences for previously documented sex differences in developmental trajectories, such as the faster acquisition of vocabulary in female infants [34], and have implications for early parent-mediated play interventions.

C. Hypotheses

The present study observed infant-parent object play by using head-mounted eye-tracking methods to investigate the effect of infant sex on infant and parent attention behaviors (distribution of attention, attention shifting, and dyadic JA). Our hypotheses are: (1) female infants will look more and longer at parent hands and face, while male infants will look more and longer at objects in addition to shifting their attention more, (2) parents of female infants will look more frequently and longer at regions of interest, and (3) parent-female dyads will exhibit more frequent and longer JA experiences.

II. METHOD

A. Participants

103 parent-infant dyads with typically developing infants aged from 3.9 to 18.6 months (Boys: N = 45, M = 11.12, SD = 4.00, 42 mothers, 3 fathers; Females: N = 58, M = 11.02, SD = 4.62, 53 mothers, 5 fathers) participated in the current study. An additional 14 dyads were recruited but not included in the current analysis due to incomplete data collection, which resulted from infant fussiness, technical equipment failure, or inadequate recording quality (e.g., not meeting the minimum calibration correlation).

B. Procedures

Parent participants completed informed consent forms upon arrival at the lab where the study took place. Once all forms were completed, parent-infant dyads were directed to the experimental room in which the play session took place. All dyads received a gift card, a family pass to a local children's museum, and an infant-sized T-shirt or stuffed animal. All parent participants provided informed consent, and the study and its procedures were approved by the university's Institutional Review Board where the research took place.

All parent-infant dyads completed in full a 5-minute and 20-second semi-naturalistic object play session with eight unique toy objects (a basket, a bear, a bunny, a car, a carrot, a cookie, a cup, and a jar) that have been used in previous infant head-mounted eye-tracking studies [35], [36], [37] and which correspond to the earliest learned nouns per the MacArthur-Bates Communicative Developmental Inventory: Words and Gestures form (MCDI: WG), which is a commonly-used infant vocabulary checklist. [38] During the play session, parents and infants sat across from each other at a 60 x 60 x 40 cm table while wearing head-mounted eye trackers. Parents and infants both completed a calibration procedure before and after the object play session, which trained research assistants administered. Parent participants were instructed to play with their child as naturally as possible during the object play session. Set-up, calibrations, and the play session take approximately 20 minutes to complete.

Watec (WAT-230A) miniature color cameras with supplementary eye trackers (weighing 51g in total), developed by Positive Sciences, Inc., [39] were used for recording the object play session. One camera faces the participant's right eye and records their pupil movements and corneal reflection while a second camera placed on the forehead records the visual field (scene) from the participant's perspective (FPV: 54.4° horizontal by 42.2° vertical). Correspondence between the eye camera and the forehead-mounted camera was achieved using a manual calibration procedure before and after the play session for each participant. A 60 x 40 cm board with nine spatially distributed stickers was placed facing the participant and trained research assistants directed the participant's attention to each sticker in a random order (such as by pointing to the sticker for parents or placing a salient toy in front of the sticker for infants). Calibration was determined post hoc through the Yarbus software program, which estimates the location of the participant's eye gaze on the scenery image captured from the participant's forehead camera [39]. A minimum calibration correlation of 0.9 between both cameras was obtained for each participant.

Two additional digital video cameras mounted on the wall and ceiling respectively captured an overall view of the play session alongside an audio recording. All videos were recorded and rendered at 30 frames per second before being synchronized together by the Adobe Premiere software program. On average, each parent-infant dyad had 8,821 frames (*SD* = 497) recorded during the play session which were annotated and used for the current analysis. Inaccessible frames included eye blinks, infant fussiness, and play-session interruptions.

C. Behavioral Annotation

Each dyad's play-session video was imported into the Datavyu software program [40] for manual frame-by-frame behavioral annotation of the play-session by trained coders. We measured reliability by randomly selecting 25% of the frames for each parent-infant dyad and assessing the inter-rater coding agreement for both the infant's and the parent's gaze behaviors. Inter-rater reliability for infant gaze was an average of 84% and 86% for parent gaze. These reliability rates match the reliability ranges used in head-mounted eye-tracking studies with infants of similar ages [36], [41], [42]. Infant and parent gaze patterns were identified by the location of the calibration dot on the respective scene view for four

regions of interest (ROIs): (1) face, (2) toy objects, (3) parent's hands, and (4) infant's hands. These targets were chosen as they are the most common images captured in person-centered viewing and have been used in previous head-mounted eye-tracking studies involving parent-infant play [20].

After infant and parent gaze patterns were coded separately, the data streams were synchronized to identify JA moments (in which both parent and infant looked at the same object simultaneously). JA moments were further classified as initiation of JA (IJA; when infants looked at the object first) and response to JA (RJA; when parents looked at the object first). We calculated the frequency, duration, and average duration of both infant and parent attention distribution to the four ROIs alongside the joint attention measurements. To investigate attention shifting, we classified the ROIs as social (face, parent hands, and infant hands) or non-social (objects). We calculated the frequency of infant and parent attention shifting between each type (i.e., social to social, social to non-social, non-social to non-social, and non-social to social).

D. Data Analysis Approach

A series of multivariate analyses of variance with infant age as a covariate (MANCOVA) were conducted to address the current research questions. This approach allows for reduced potential of Type I error compared to multiple univariate analyses and accounts for intercorrelation among the dependent variables as well as potential variations among dyads [43]. The models included (1) infant attention distribution, (2) infant attention shifting, (3) parent attention distribution, (4) parent attention shifting, and (5) parent-infant JA behaviors.

III. RESULTS

A. Infant Gaze Distribution

A series of MANCOVA models with infant age as a covariate in the frequency, duration, and average duration of infant attention to the four ROIs were used to explore the effect of infant sex. First, a MANCOVA in the frequency of infant attention to the four ROIs found a significant effect of the infant sex group, $F(4, 99) = 2.534$, $p = .045$, Wilks' $\Lambda = .907$, partial $\eta^2 = .093$. A significant infant age effect was also present, $F(4, 99) = 4.289$, $p = .003$, Wilks' $\Lambda = .852$, partial $\eta^2 = .148$. The follow-up univariate analysis for each of the four ROIs found a significant effect of infant sex on the frequency of infant attention to the parent's hands and the infant's own hands: male infants looked more frequently at their parent's hands and their own hands, $F(1, 102) = 6.993$, $p = .009$, and $F(1, 102) = 4.215$, $p = .043$, respectively. A significant effect of infant age on the frequency of infant attention to objects and the infant's own hands was also found: infants looked more frequently at objects and their own hands as infants became older, $F(1, 102) = 4.558$, $p = .035$, and $F(1, 102) = 4.327$, $p = .040$, respectively.

Second, a MANCOVA in the duration of infant attention to the four ROIs showed no difference between infant sex groups, $F(4, 99) = 1.305$, $p = .273$, Wilks' $\Lambda = .950$, partial $\eta^2 = .050$. However, there was a significant effect of infant age, $F(4, 99) = 2.807$, $p = .030$, Wilks' $\Lambda = .898$, partial $\eta^2 = .102$. The follow-up univariate analysis for each of the four ROIs found a significant effect of infant age on the duration of infant attention to the infant's own hands: infants looked longer at their own hands as infants became older, $F(1, 102) = 4.609$, $p = .034$.

Third, a MANCOVA in the average duration of infant attention to the four ROIs showed no difference between infant sex groups, $F(4, 102) = .318$, $p = .811$, Wilks' $\Lambda = .954$, partial $\eta^2 = .046$.

B. Infant Attention Shifting

A MANCOVA model with infant age as a covariate was used to investigate the frequency of infant attention shifting between each type (i.e., social to social, social to non-social, non-social to non-social, and non-social to social). There was no significant effect of infant sex group nor was there a significant age effect; $F(4, 99) = 2.150$, $p = .080$, Wilks' $\Lambda = .920$, partial $\eta^2 = .080$, and $F(4, 99) = 2.130$, $p = .083$, Wilks' $\Lambda = .921$, partial $\eta^2 = .079$, respectively. However, both effects were shown to be marginal. The follow-up univariate analysis indicated a significant effect of infant sex on the frequency of attention shifting between the social and non-social ROIs: male infants shifted their attention from non-social to social ROIs, $F(1, 102) = 4.992$, $p = .028$, social to social ROIs, $F(1, 102) = 4.673$, $p = .033$, and social to non-social ROIs, $F(1, 102) = 5.015$, $p = .027$, more frequently. There was also a significant effect of infant age on the frequency of attention shifting between the non-social and non-social ROIs: infants shifted their attention from non-social to non-social ROIs, $F(1, 102) = 6.372$, $p = .013$, as infants became older.

C. Parent Gaze Distribution

A series of MANCOVA models with infant age as a covariate in the frequency, duration, and average duration of parent attention to the four ROIs were used to determine the effect of infant sex. First, a MANCOVA in the frequency of parent attention to the four ROIs indicated a significant effect of the infant sex group, $F(4, 95) = 3.484$, $p = .011$, Wilks' $\Lambda = .872$, partial $\eta^2 = .128$. A significant infant age effect was also present, $F(4, 95) = 7.019$, $p < .001$, Wilks' $\Lambda = .772$, partial $\eta^2 = .228$. The follow-up univariate analysis for each of the four ROIs found a significant effect of infant sex on the frequency of parent attention to the infant's hands: parents of male infants looked more frequently at the infant's hands, $F(1, 98) = 6.958$, $p = .010$. A significant effect of infant age on the frequency of parent attention to objects and the infant's hands were also found: parents looked more frequently at objects and the infant's hands as infants became older, $F(1, 98) = 14.180$, $p < .001$ and $F(1, 98) = 14.354$, $p < .001$ respectively.

Second, a MANCOVA in the duration of parent attention to the four ROIs indicated a significant effect of the infant sex group, $F(4, 95) = 2.805$, $p = .030$, Wilks' $\Lambda = .894$, partial $\eta^2 = .106$. A significant infant age effect was also present, $F(4, 95) = 4.323$, $p = .003$, Wilks' $\Lambda = .846$, partial $\eta^2 = .154$. The follow-up univariate analysis for each of the four ROIs indicated a significant effect of infant sex on the duration of parent attention to objects: parents of female infants looked longer at objects, $F(1, 98) = 4.060$, $p = .047$. A significant effect of infant age on the duration of parent attention to

objects and the infant's hands was also found: parents looked longer at objects and the infant's hands as infants became older, $F(1, 98) = 7.378$, $p = .008$ and $F(1, 98) = 5.935$, $p = .017$ respectively.

Third, a MANCOVA in the average duration of parent attention to the four ROIs showed no difference between infant sex groups, $F(4, 95) = .396$, $p = .811$, Wilks' $\Lambda = .983$, partial $\eta^2 = .017$.

C. Parent Attention Shifting

A MANCOVA model with infant age as a covariate was used to investigate the frequency of parent attention shifting between each type (i.e., social to social, social to non-social, non-social to non-social, and non-social to social). There was no difference between infant sex groups, $F(4, 95) = .350$, $p = .843$, Wilks' $\Lambda = .985$, partial $\eta^2 = .015$. However, there was a significant effect of infant age, $F(4, 95) = 3.485$, $p = .011$, Wilks' $\Lambda = .866$, partial $\eta^2 = .134$. The follow-up univariate analysis found a significant effect of infant age on the frequency of attention shifting between the social and non-social ROIs: parents shifted their attention from non-social to non-social ROIs, $F(1, 98) = 12.547$, $p < .001$, non-social to social ROIs, $F(1, 98) = 6.492$, $p = .012$, and social to non-social ROIs, $F(1, 98) = 6.484$, $p = .013$, more frequently as infants grew older.

D. Joint Attention

A series of MANCOVA models with infant age as a covariate in the frequency, duration, and average duration of the three types of JA behaviors were used to test the effect of infant sex. First, a MANCOVA in the frequency of the JA behaviors found no difference between infant sex groups, $F(3, 96) = .547$, $p = .580$, Wilks' $\Lambda = .989$, partial $\eta^2 = .011$. However, there was a significant effect of infant age, $F(3, 96) = 5.113$, $p = .008$, Wilks' $\Lambda = .903$, partial $\eta^2 = .097$. The follow-up univariate analysis found a significant effect of infant age on the frequency of JA and RJA: infants had more frequent JA and RJA moments as they became older, $F(1, 98) = 6.140$, $p = .015$, and $F(1, 98) = 10.124$, $p = .002$, respectively.

Second, a MANCOVA in the duration of the JA behaviors indicated no difference between infant sex groups, $F(3, 96) = 1.635$, Wilks' $\Lambda = .950$, partial $\eta^2 = .050$. However, there was a significant effect of infant age, $F(3, 96) = 3.373$, $p = .008$, Wilks' $\Lambda = .903$, partial $\eta^2 = .022$. The follow-up univariate analysis indicated a significant effect of infant age on the duration of JA and RJA: infants had longer JA and RJA moments as they became older, $F(1, 98) = 4.297$, $p = .041$, and $F(1, 98) = 9.389$, $p = .003$, respectively.

Third, a MANCOVA in the average duration of the JA behaviors indicated a significant effect of the infant sex group, $F(3, 96) = 3.139$, $p = .029$, Wilks' $\Lambda = .909$, partial $\eta^2 = .091$. The follow-up univariate analysis found a significant effect of infant sex on the average duration of JA, RJA, and IJA: parent-female dyads had longer average JA moments, $F(1, 98) = 8.331$, $p = .005$, RJA moments, $F(1, 98) = 5.300$, $p = .023$, and IJA moments, $F(1, 98) = 8.224$, $p = .005$.

IV. DISCUSSION

The present study documented the effect of infant sex on attention behaviors during an interactive object play session through the use of a head-mounted eye-tracking method. Specifically, we examined infant and parent attention distributions, attention shifting, and JA moments.

Our hypotheses were: (1) female infants will look more and longer at parent hands and face, while male infants will look more and longer at objects in addition to shifting their attention more, (2) parents of female infants will look more frequently and longer at regions of interest, and (3) parent-female dyads will exhibit more frequent and longer JA experiences. Our findings partially supported hypothesis (1), revealing that male infants exhibited more frequent attention toward hands and attention shifts overall. Our findings also partially supported hypothesis (2), revealing that parents of male infants more frequently looked at ROIs (specifically infant's hands) while parents of female infants looked longer at ROIs (specifically objects). Finally, our findings also partially supported hypothesis (3), as parent-female dyads showed longer average durations of JA experiences.

A. Socially Coordinated Sex Effect

First, male infants showed more attention to hands and more attention shifts. These findings extend previous work reporting increased attention shifting among male infants during computer-based tasks [7]. Considering the present results observed during infant-parent interactive play, parents may play an influential role in the generation of these attention behaviors. It is worthwhile to note that until infants are approximately 18 months of age, parents are the driving force behind object engagement during play (i.e., they hold objects more frequently than infants hold objects) [31]. One speculation is that through parental scaffolding, infants' visual exploration might be tightly coupled with their looking at parental hands, and as they age, their visual exploration becomes lightly linked to their own hands. This indicates a possible collaboration between infants and parents that contributes to the resulting infant sex effect. We also add to the growing body of literature that has documented differences in parental behaviors toward female infants compared to male infants. In the current study, parents of male infants looked more frequently at ROIs (specifically infant hands) while parents of female infants looked longer at ROIs (specifically objects). The role of parental scaffolding behaviors in guiding the dynamics of infant visual experiences therefore may contribute to the infant sex differences found in the current study. However, further research is required to examine how such parental attention behaviors directly influence that of their infant and whether or not they co-occur with differences in other forms of scaffolding, such as object handling and labeling. This knowledge can then in turn be leveraged to inform early infant interventions that are delivered by parents during interactive play. For example, if an intervention focuses on increasing parent attention to objects during play, parents of male infants may require more frequent and/or longer training sessions to see improved outcomes, while the opposite may be true if the intervention sought to increase parental attention to their infant's hands.

B. Dyadic Route for Sex Dependent Developmental Trajectories

Male infant attention to hands also allows them to better navigate their attention to the handled object, which opens the

door to learning about the object in real-time from their parent [31], [42]. Considering that previous research has indicated a preference for male infants to look at non-social motion (e.g., racing cars) over social motion (e.g., a human face talking) [8], one may argue that male infants are directing their attention more towards the motion of hands moving the objects during the play-session than female infants are. This preference necessitates increased attention shifting, compared to simply looking at their parent's face. These sex-based differences may be rooted in early sensory-motor processes that are driven by visual experiences, potentially contributing to male advantages in early gross motor development [44], [45]. The present findings also indicate that parent-female dyads experienced longer average JA, IJA, and RJA moments. This 'advantage' could be influenced by early-developed social-communication behaviors and processes that have been reported to have a female social 'advantage' among infants, such as social eye contact [10], social perception [9], and facial expression processing [46]. These studies suggest that the sex differences in social communication extend into childhood, adolescence, and adulthood [46]. Additionally, as JA has been shown to directly influence other developmental domains, such as language, the results of the present study may reflect the documented earlier acquisition of language by females compared to males [34]. The findings of differential attention behaviors based on infant sex raise the question of how important these sex differences are in facilitating active learning and how they contribute to later developmental trajectories (e.g., communication and motor skills) that have been linked to sex differences and are directly influenced by attention behaviors. For example, male participants showed more attention to hands and more frequent attention shifting. Does this mean that male infants should be encouraged to look at a target for longer or shift their attention between targets more often? The present results raise important questions regarding the significance of early parent-infant interactions in our understanding of sex differences in learning and development.

C. *Task-Specific Nature of Sex Differences in Attention*

Our observational results did not replicate the previously documented experimental study results showing infant sex differences in attention to face (for males *or* females). The different outcomes could be attributed to that the previous studies typically utilized computer-based experimental tasks or still-face trials which may measure "attention capacity" rather than capturing *attention experiences* in the social context [9]. Infants may also demonstrate different attention behaviors to the faces of experiment administrators (i.e., strangers) in those studies using computer-based experimental tasks and still-face trials than their less novel parents [11], [47]. Furthermore, measuring attention to face through third-party observations by research assistants introduces potential reliability and subjectivity issues compared to the more direct measure of gaze behaviors captured by head-mounted eye-tracking methods [48].

Some limitations need to be considered when interpreting the results of the current study. One concern regards the infants' age. The present study sample included infants from a wide age range (3-18 months), which takes place before the period of rapid vocabulary growth among infants older than 18 months. However, this may still generate variability in infants and parent behaviors, such as language (as infants start to learn and produce words) and motor (as infants begin to crawl and walk), and could lead to a reduced ability to detect significant group effects (i.e., decreased power). To address this potential issue, we controlled for infant age in the analyses and documented its effect in the current study. Further validation work (e.g. exploring the interaction between infant sex and age) would extend our understanding of the developmental nature of sex differences.

Another potential limitation concerns the parents' gender distribution. Many studies investigating early parent-infant social interaction use mothers [13], [42] and we, too, had a majority of our samples being mothers (95 mothers compared to 8 fathers). However, literature has indicated differences in mother-infant play behaviors compared to father-infant play behaviors [23], [28]. Though the concern regarding the parent sex effect is outside the scope of the present research, including more fathers in future studies would help us generalize these findings across dyads and further understand how the infant sex effect is general or specific to the sex of the parent social partner.

Nonetheless, the present study focusing on naturally occurring social attention revealed the effect of infant sex on infant and parent attention behaviors during interactive play for the first time. The present study highlights the early emergence and rapidly changing characteristics of infant attention and how parents modify their attention behaviors based on their infant's sex and age.

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