

# Bidirectional Mechanisms rather than Alternatives: The Role of Sustained Attention in Interactive Contexts Can Only Be Understood through Joint Attention

Commentary on Hudspeth and Lewis

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Joint attention · Sustained attention · Child-parent dyad

## Introduction

Although associations between joint attention and infant development have been extensively investigated (e.g., Carpenter et al., 1998; Donnellan et al., 2020; Mundy & Newell, 2007), the question of how, exactly, interactive behaviours support infant learning remains widely debated (Abney et al., 2020; Tomasello et al., 2007). Hudspeth and Lewis (this issue, DOI 10.1159/000515681) suggest that measures of joint attention in early interaction with an adult partner might merely reflect the ability of the infant to sustain their attention. This theory places infant object engagement at the forefront of attention and learning in joint interaction, in contrast to more traditional views that emphasise infants' engagement with the attentional behaviours of their adult partner (e.g., Carpenter et al., 1998). First, we discuss Hudspeth and Lewis's comments on methodological issues to do with defining sustained attention. Next, we consider an important point

that they do not mention – namely, the inconsistencies in defining joint attention in the literature. We end by exploring endogenous and exogenous influences on sustained and concurrent looking in early interaction, as well as their implications for understanding infant learning.

## Methodological Issues to Do with Defining Sustained Attention

Hudspeth and Lewis (this issue) are correct to point to some of the methodological and theoretical challenges involved in defining sustained attention (see previous discussions of this here: Aslin, 2007; Csibra et al., 2016; Wass, 2014). However, when they highlight the discrepancy between earlier studies which suggest that shorter looking times associate with better long-term outcomes, and more recent studies which suggest that longer looking times associate with better outcomes, they miss two important points. The first of these is the age of the infants, and the second is the context in which the looking is assessed. The earlier literature, which has been reviewed by Colombo and Mitchell (2009), points to a well-repli-

cated but moderate-sized negative association between looking durations towards static images in infants less than 8 months old and cognitive outcomes during later development (i.e., shorter looks associated with better outcomes). The more recent literature points to a positive association between looking durations during naturalistic joint play in infants older than 12 months and cognitive outcomes during later development (i.e., longer looks associated with better outcomes; e.g., Brandes-Aitken et al., 2019).

A full discussion of the reasons why these different relationships are observed is beyond the scope of this commentary. Briefly, however, one study found that, whereas looking behaviour towards static images declined throughout the first year, looking behaviour towards more complex stimuli showed a U-shaped trajectory – decreasing initially, then increasing thereafter (Courage et al., 2006). The authors suggested that this may be because look durations are influenced by two factors: encoding speed (which gets faster with increasing age) and endogenous sustained attention (which increases with age, starting from the end of the first year of life, but only for complex/engaging images; Courage et al., 2006; see also Colombo & Cheatham, 2006). This may be part of the reason why the direction of the correlation between looking duration and long-term outcomes depends on the context in which the looking is assessed, and the age of the infants.

The authors point, correctly, to the importance of using physiological information to identify “good-quality” visual attention – an approach that was pioneered by Richards (2010). We would, however, contest their claim that these physiological benchmarks are not consistently defined: Richards’ (1980) work was developed and tested with great care, and the criterion that heart rate defined sustained attention should be operationalised as five consecutive beats below a median defined during the pre-stimulus interval has been applied consistently across numerous studies by Richards (2010) and others (e.g., Colombo et al., 2010). Also, of note, several studies have shown that heart rate defined sustained attention associates with better stimulus encoding (reviewed by Richards, 2011). For example, infants are better able to recognise material that was presented during phases of heart rate decelerations (Frick & Richards, 2001; Richards, 1997), and infants are also less distractible during heart rate decelerations (Casey & Richards, 1988; Lansink & Richards, 1997). The use of endogenous markers such as physiological arousal to explore sustained attention in joint interaction is discussed below.

## Methodological Issues to Do with Defining Joint Attention

There is little consensus on the definition of joint attention in the literature, an important point that is not considered by Hudspeth and Lewis (this issue). The authors’ key tenet, that joint attention may in fact measure the infant’s ability to sustain their attention in an interactive exchange, assumes that definitions of sustained and joint attention are overlapping. Implicit in this suggestion is that infant engagement with objects is the most important aspect of how infants attend in interactive contexts, and that look durations support learning. This contrasts with much previous work on early interaction that has instead emphasised infant engagement with the attentional behaviours of their social partner (e.g., Carpenter et al., 1998).

The article cited as supporting the view that infant sustained, rather than joint, attention during shared interaction predicts language learning uses an objective measure of joint attention (Yu et al., 2019). Yu et al. (2019) used head-mounted eye trackers to record parent and infant gaze behaviour whilst they engaged in shared table-top play with objects. They define bouts of joint attention as a continuous alignment of parent and infant fixation towards the same object that lasts longer than 500 ms, including looks briefer than 300 ms elsewhere. Fundamental to their definition of joint attention, therefore, is the concurrent looking of parent and infant towards the same object, excluding moments where each partner briefly looks towards the other’s face or another object.

More traditional definitions of joint attention, however, emphasise attention-sharing, or the ability of the infant to co-ordinate their attention with the social partner, rather than concurrent looking (Carpenter et al., 1998; Mundy et al., 2007). In these accounts, to achieve a bout of joint attention, infants must not only engage with the object that the adult is also focussed on, but demonstrate an awareness of the adult’s attention by exchanging looks between their partner and the object of mutual interest (Carpenter et al., 1998; Tomasello et al., 2007). These definitions of joint attention further differentiate between responding to joint attention, where infants follow their social partner’s attention towards an object, indicated by gaze or gesture (Gaffan et al., 2010; Mundy et al., 2007), and initiating joint attention, where infants initiate the attention of the adult partner through, e.g., pointing and/or looking towards the partner’s face to signal their intention to share information (e.g., Mundy & Newell, 2007).

Under shared attention definitions of joint attention, there is little overlap with sustained attention. In fact, if

joint attention is measured as co-ordinated attention, where frequent shifts of attention from object to partner are key, a negative relationship between joint attention and sustained attention would be predicted, with longer look durations potentially associating with less attention-sharing. This has implications for investigating associations between joint attention and learning.

Accounts emphasising the co-ordinated aspect of joint attention argue that developments in joint attention support infant word learning because shared attention enables infants to understand the referential intent of the speaker (Abney et al., 2020; Brooks & Meltzoff, 2008, 2015). Investigating how often infants followed the gaze of an adult experimenter towards objects placed on either side of a table, Brooks and Meltzoff (2008) found that the frequency with which infants aged 10–11 months gaze-followed, and the duration of their looking towards the target object, predicted faster vocabulary growth from 12 to 24 months. Under this view, it is infant engagement with the attentional and communicative behaviours of their adult partner that predicts learning, rather than infant engagement with the object itself. This suggests that sustained attention towards objects in joint play is perhaps a less meaningful construct to investigate.

That said, similar to the Brooks and Meltzoff (2008) study, much research on co-ordinated joint attention and its relationship to language learning has been conducted using experimental paradigms. In these paradigms, an experimenter engages in behaviours aimed at eliciting either a response to their initiations for shared attention in the infant (responding to joint attention), or an initiation for shared attention by the infant (initiating joint attention; Mundy & Newell, 2007). Few studies have explored how often infants engage in co-ordinated attention during free-flowing interactions (Wass et al., 2018a; Yu et al., 2019), and a recent study conducted by Abney et al. (2020) has actually shown that the occurrence of these behaviours among infants during naturalistic play is rare.

Recording gaze behaviour using head-mounted eye trackers from infants aged 12 months and their parents, Abney et al. (2020) computed the proportion of time infants spent in triadic attention. Triadic attention was defined as periods where both adult and infant looked towards the same object, and the infant alternated their gaze between the object and their partner's face at least once. They showed that infants spent less than 1% of the interaction in triadic attention, whilst 86% was spent looking towards objects. In contrast, parents looked towards objects 33% of the time, spending 15% engaging in triadic attention, and another 15% looking to the infants' face

whilst the infant engaged with an object (Abney et al., 2020). These findings suggest that infant attention-sharing behaviours are very infrequent in naturalistic play; the length of time infants spend looking towards objects without looking to their partner provides strong reason, as Hudspeth and Lewis (this issue) suggest, to investigate the temporal patterns and durations of infant object looks. The frequency with which parents monitor their infant's gaze also suggests, however, that infant looks cannot be studied in isolation. How adults co-ordinate attention with their infant should be a key focus, too.

### **Endogenous and Exogenous Influences on Infant Attention in Interactive Contexts**

If sustained attention and concurrent looking are meaningful constructs to study in joint interaction, how might we investigate the function of sustained attention in interactive contexts? We agree with Hudspeth and Lewis (this issue) that we must start by exploring the associations between sustained and concurrent attention in shared interaction (Yu et al., 2019). The authors consider that, rather than being synonymous with each other, developments in sustained attention might drive developments in joint attention, or vice versa. An alternative view, however, is that developments in the broader construct of executive control, or volitionally controlled attention, drive increases in both sustained and joint attention. Indeed, as well as explaining increases in sustained attention (Colombo, 2001; Colombo & Cheatham, 2006), the maturation of the executive attention system towards the end of the first year is also thought to drive the emergence of infant-initiated joint attention, as well as attention-sharing behaviours in joint interaction (Mundy et al., 2007).

Alternatively, it could be the case that in shared play, concurrent attention and sustained attention are largely influenced by the parent's behaviour. Findings by Abney et al. (2020) suggest that the adult's role in joint play is to monitor the attention of their infant through flicking between objects and infant gaze whilst the infant attends towards the objects. In monitoring and responding to the attentional behaviours of their infant, perhaps parents are largely responsible for creating moments of concurrent attention, and, in doing so, sustaining their attention towards objects.

The authors end by considering how we might approach studying relationships between sustained attention and learning across interactive and non-interactive

contexts. One suggestion made by Hudspeth and Lewis (this issue) to further our understanding of sustained attention in shared play is to factor out the influence of the social partner on the infant's attention. They do not detail how this might be explored and it is unclear whether this would be possible. Perhaps a more meaningful approach, instead, is to identify differences and/or potential similarities in the mechanisms driving associations between infant attention and learning in both contexts.

As Hudspeth and Lewis (this issue) point out, in shared, interactive, contexts, the association between factors endogenous to the infant and their attention, such as decelerations in heart rate, that we can reliably identify and use as markers for attention and learning when infants are studied in isolation (e.g., Richards & Gibson, 1997), are attenuated. For example, Wass et al. (2018b) have shown that during joint table-top play with an adult partner, the relationship between infant endogenous oscillatory neural activity and infant attention is much reduced, compared to where infants explore toys on their own. Recording dual EEG from parents and infants during naturalistic play, cross-correlation analysis showed that infant theta activity significantly forward-predicted infant attention during the solo play condition where infants played with objects on their own. During joint play, this association decreased, with infant attention tending to proceed changes in infant theta activity.

The solo play findings are consistent with much previous work showing associations between theta activity and infant attention, as well as processes related to information encoding (Begus et al., 2015; Orekhova et al., 2006). That infant looking shows less of an association with endogenous drivers of attention in shared interaction suggests that exogenous influences largely determine how infants allocate their attention. Discussion on the implications of these findings for identifying markers of infant learning in shared interaction is beyond the scope of this commentary; relevant literature on the association between parent behavioural responsiveness and infant language outcomes is briefly discussed below.

In line with the finding that parents frequently monitor their infant's attention during shared play (Abney et al., 2020), a substantial body of literature documents associations between increased parent responsiveness to their infant's cues and superior vocal learning (e.g., Baumwell et al., 1997; Goldstein & Schwade, 2008; Gros-Louis et al., 2014; Tamis-LeMonda et al., 2001; see Tamis-LeMonda et al., 2014 for a review). Taken together, a crucial implication of these findings is that the timing of parent behaviours, rather than infants' sustained attention towards ob-

jects, predicts what information is encoded by the infant during an interactive exchange. Alternatively, and supported by the reduced association between endogenous oscillatory activity and infant attention in shared play (Wass et al., 2018b), temporal sensitivity of parents to their infant's behaviour might instead drive and sustain infant attention, meaning parent input arrives where infants are most receptive to receiving new information.

Overall, therefore, investigations into the functional significance of sustained attention in interactive contexts need to consider the behaviours of not just one, but both interacting partners, with an emphasis on how episodes of concurrent attention are achieved. Whether and how endogenous neurophysiological markers of early information processing can be identified in shared interaction should be a key focus.

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### Statement of Ethics

No ethical approval was required for the preparation of this conceptual paper as no human or animal subjects were used.

### Conflict of Interest Statement

The authors declare that they have no competing interests.

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### Author Contributions

E.A.M. Phillips and S.V. Wass co-wrote this article.

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