The developmental origins of joint attention and communication in infancy

Gideon Salter

A thesis submitted for the degree of PhD
at the
University of St Andrews

2022

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GENERAL ACKNOWLEDGEMENTS

These acknowledgements are to the many people who have provided their support, encouragement and guidance over the past four and a half years.

To those who have been part of the School of Psychology and Neuroscience over the past few years. Thank you to the staff who made it such a collegial and rewarding place to study. Thank you to those in the office, the cleaning team, and the workshop who have all been a help in different ways. Thank you to all the research assistants who gave their time and energy to help with testing and coding. Thank you to the ABC lab for enjoyable meetings and helpful discussions. Thank you to Amanda for bringing me into your research group, and for being generous with your time and guidance. Thank you to Filippo for your help with the statistical analyses. Many thanks to Geraldine for all your help with the project, outreach programs and the Baby Bee.

To the friends who have also been on the PhD journey. I will fondly remember the Aikman's basement gatherings, the PubHDs, the quiz nights and the meals we shared together. I am grateful to all those who have passed through the White Office. Thank you to Laras and Lucy for sharing in the developmental psychology journey from the very beginning, and providing much needed space to complain and commiserate!

To the mums and babies that took part in the study, and those who were part of the Baby Bee. I was extremely fortunate to have such an enthusiastic, patient and insightful group. Thank you to the mums for making time despite all the many pressures and challenges of life with an infant of that age. Thank you for the thoughtful comments and reflections. The babies were an absolute delight, and challenged my preconceived notions about what infant development is supposed to look like.

To Josh. Thank you for the chance to step out of my intellectual bubble, for the conversations and projects that have always been enjoyable and stimulating. Thank you for the times spent sharing the ups and downs of English football!

To those at St Andrews Baptist Church. Thank for being a community of love and support over these past years, for me personally but also for our family. Thank you Andrew, Mark, and Paulus, who each gave their time to provide pastoral and spiritual support.

To my new family. Thank you for welcoming me with open arms. Thank you Patrick, Caroline, Peter, Lizzie and Junio for the numerous ways you have supported Becky and I, both in our relationship and time as parents. Thank you for introducing me to Ugandan Scrabble and Contract Whist!

To my family; grandparents, aunts, uncles, cousins and partners. I am very grateful to have a family who I love to be around! I am very grateful for the times where I could step away from the PhD to have fun and relax with you all. Thank you especially Sammy, Sarah, Nathanael and Miri for your support, and thank you for welcoming Becky into your lives in these past few years. Thank you to Keziah, Jemimah and Lazarus for always putting a smile on my face!

To Mum and Dad. Thank you for making your home somewhere that has always been a restful place. Thank you for your love and support through the ups and downs of the past years, and for your support for Becky and I in our relationship, marriage and start of parenthood.

To Nanny, who is sadly not with us to share in this milestone, but who I want to acknowledge and honour nonetheless.

To Malinda. You have been every bit the skilled and meticulous researcher who was recommended to me when I first started to seek out a supervisor. Thank you for helping me become a more focused, rigorous researcher, and for sharpening my thinking and writing. But more than that, thank you for your genuine care and desire to see me succeed.

To Becky. This thesis is dedicated to you above all! It would not be finished without the grace you have shown me and the support you have been. Thank you for your love and patience, for being there in the joyful times and the most difficult times. I am so fortunate to have someone with your strength, courage and kindness by my side, and I love you very much! What an amazing blessing you are!

To Ava. Every day in the challenging final months of thesis writing, I knew I would arrive home to have my heart warmed by your beautiful smile and playful personality. Thank you for being a daily reminder of how blessed I am. I love you so much!

Psalm 131

FUNDING

This work was supported by a scholarship from the School of Psychology and Neuroscience at the University of St Andrews.

ABSTRACT

Despite widespread recognition of the importance of joint attention, there are still disagreements regarding its definition and development. There are questions over when and how joint attention emerges, what exactly makes it joint, and its relation to communication. These developmental and definitional questions are closely linked, and thus to understand joint attention we must understand the very beginnings of its development and its relation to communication. This thesis aimed to further our understanding of joint attention by investigating infants' development in the key period leading up to 9 months.

The thesis reports a comprehensive longitudinal study of infants aged 6 to 10 months (with additional data collected remotely at 11 and 12 months), using experimental, observational, interview and questionnaire methods. First, it investigated the very beginnings of infants' capacity to initiate joint attention, finding that this ability emerges for some infants by 6 months. Next, it examined the very beginnings of infants' gestural communication, identifying developmental processes that precede the emergence of some of infants' earliest conventional communicative gestures. It also examined a range of other social (e.g. imitation), cognitive (e.g. means-ends understanding) and motor skills (e.g. self-locomotion) in order to identify relations between key social and non-social abilities emerging in this period. These abilities typically emerged gradually, starting before 9 months, with limited relations found amongst them. Finally, the study examined the relations between maternal

and researcher assessments of communication and motor skills, identifying ways to increase consistency between these assessments.

Overall, the thesis shines new light on the very beginnings of joint attention and communication in infancy. It demonstrates that infants' capacity to engage in joint attention emerges for some infants by 6 months of age, and highlights the importance of investigating the processes that lead to the emergence of joint attention and communicative abilities.

CHAPTER 1

INTRODUCTION

From the earliest months of their lives, human infants seek to connect with others through responsive social interactions (Stephens & Matthews, 2014; Trevarthen & Aitken, 2001). Across their first year, these interactions occur in increasingly complex ways. By the time infants have reached their first birthday, the vast majority are engaging in shared experiences of the world around them. These experiences are often called "triadic", involving a three-point relation between another person and a feature of the world, as opposed to "dyadic" (two-point, person-to-person) engagement (Bakeman & Adamson, 1984). One-year-old infants across different cultures take part in varying forms of triadic engagements with caregivers (Callaghan et al., 2011; Little et al., 2016; Salomo & Liszkowski, 2013), incorporating objects, events and other stimuli in their engagements with others. They also use communicative gestures to draw others' attention to interesting stimuli, such as showing (Cameron-Faulkner et al., 2015) and pointing gestures (Liszkowski et al., 2012). The ability to share attention to some feature of the world with another has been called "joint attention" (Scaife & Bruner, 1975).

Though originally studied in infant-caregiver interactions, the concept has been employed in research across a range of ages (e.g. with pre-school children, Psouni et al., 2019; Wolf & Tomasello, 2020 and adults Shteynberg, 2018; Shteynberg et al., 2016), and there have been debates over the capacity of non-human animals to engage in joint attention (Ben Mocha et al., 2019; Carpenter & Call, 2013; Leavens & Racine, 2009). The term has featured prominently in theories of shared intentionality and cultural cognition (Tomasello, 1999, 2019; Tomasello et al., 2005; Veissière et al., 2020). It has also attracted considerable interest in philosophy, with many philosophers arguing that it can prove helpful in addressing thorny issues such as to mutual knowledge, communication and knowledge of other minds (Eilan et al., 2005; Seemann, 2011).

Despite widespread recognition of the significance of joint attention, there are fundamental questions that continue to spark debate. First is the definitional question: what exactly is joint attention? There are still substantial disagreements regarding how to understand joint attention (Reddy, 2018; Seemann, 2011; Siposova & Carpenter, 2019), and this issue becomes all the more pressing as joint attention is applied to a wide range of domains and issues. It is therefore necessary for more sophisticated and nuanced accounts of the concept to be developed (Gabouer & Bortfeld, 2021; Siposova & Carpenter, 2019; Stephenson et al., 2021).

The second issue is the developmental question: when and how does joint attention emerge in development? A prominent view has been that joint attention emerges suddenly at around 9 months of age (Hubley & Trevarthen, 1979; Stern, 1985; Tomasello, 1999). However, this perspective has been criticised on a number of fronts (de Barbaro et al., 2013; Hoehl & Striano, 2013; Moll et al., 2021; Reddy, 2010; Rossmanith et al., 2014), with researchers instead claiming a more gradual emergence of joint attention and other social abilities across infants' first year. There is thus a need for more data that can shed more light on the very beginnings of joint attention in development.

The definitional question and the developmental question are intertwined. As will become clear in the subsequent sections, it is not straightforward to talk about one without the other, and the introduction will seek to draw out some of the key theoretical and empirical issues that arise under these two linked questions. This introduction will proceed as follows. First, it will explore the definitional question of joint attention, exploring how the term has been used and understood since its introduction into the developmental literature. It will then highlight some of the key debates regarding the development of joint attention, particularly when and how it emerges. The final section will set the stage for the rest of the thesis, outlining how this research will address important issues that will shed light on both the definition and development of joint attention.

1.1 The Definition of Joint Attention

The earliest use of the term "joint attention" can be credited to Scaife and Bruner (1975). They demonstrated that infants are sensitive to the gaze direction of adults, and suggested that this was a means of highlighting important features of the complex environments that caregiver-infant pairs encounter. This work, and further work by Bruner (1975, 1983, 1986), was highly influential in promoting a view of the infant as a social being, a view that grew in popularity in the 1970's due to pioneering research in this domain (Bates et al., 1979; Bateson, 1975; Brazelton et al., 1975; Hubley & Trevarthen, 1979; Trevarthen & Hubley, 1978). However, there were other early pioneers of this approach, such as Werner and Kaplan (1963) and Vygotsky (1978).[1] These researchers had already articulated a view of infancy that emphasised the importance of dynamic engagements with others. Werner and Kaplan had introduced the notion of the "primordial sharing situation" (1963, p. 42), an image that in many ways represents what is later called a joint attention situation (Striano & Rochat, 1999), with infant and caregiver sharing the world together and mutually influencing one another. Vygotsky (1978) introduced the notion of the "Zone of Proximal Development" highlighting the guiding role of caregivers in shared activities with their infants. He was also an early proponent of the key role played by interpersonal, interactive processes in the

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[1] This date refers to the publication of the first English translation of Vygotsky's work, based on research that was published at the start of the 20th Century in Russian.

development of individual psychological processes, a perspective that continues to be influential in discussions of joint attention and human cognition (Moll & Tomasello, 2007).

This historical perspective is important, as it situates “joint attention” as a term that was introduced as part of a broader project to understand how infants come to understand the world through others and come to influence others’ engagements with the world. Scaife and Bruner (1975) were careful to specify that they were focused on joint *visual* attention, acknowledging that this was just one ability that infants have at their disposal to participate in interactions that involve a “meeting of minds” (Bruner, 1995). Beyond visual attention coordination, humans have a variety of ways to direct each others’ attention to the world such as through different communicative gestures (Bates et al., 1979; Carpenter et al., 1998), through language (Bruner, 1977; Tomasello & Farrar, 1986) and through touch (Botero, 2016; Gómez, 2015; Little et al., 2016).

These broad definitional considerations are relatively uncontroversial. However, the key challenge that has divided researchers of joint attention is what precisely makes joint attention *joint* (Hobson, 2005). Historically, a division has been drawn between *lean* and *rich* approaches to joint attention (Racine, 2011). Broadly speaking, lean approaches are characterised as understanding joint attention using minimal criteria such as “intentional co-orientation of two or more organisms to the same locus” (Leavens & Racine, 2009, p. 241; see also Yu & Smith, 2013). In contrast, rich approaches are those for which engaging in joint attention involves “knowing together” that the target is shared, emphasising a requirement of mentalising capacities on the part of the infant (Tomasello, 1995). However, a recent trend has been to suggest that these different definitions can be reinterpreted as different facets of a complex phenomenon (Carpenter & Call, 2013; Siposova & Carpenter, 2019; Stephenson et al., 2021). Rather than different definitions being in competition, different kinds of joint attention abilities and outcomes can be understood as involving different levels of "jointness" that are on a spectrum (Siposova & Carpenter, 2019). Thus, the joint attention abilities traditionally emphasised by "lean" and "rich" theorists can both serve important roles across development. For example, word learning is facilitated in situations of simultaneous attention to a common target, without requiring mutual awareness of that attention (Akhtar & Gernsbacher, 2008). However, joint attention but not simultaneous attention enables infants to know what others know and have experienced (Liebal, et al., 2010; Moll et al., 2007).

However, even if jointness is on a spectrum, there are still crucial distinctions to be drawn. A number of psychologists and philosophers have argued that there is a particular sense of jointness in joint attention that plays a key role in development and human social and cultural life (Carpenter & Liebal, 2011; Eilan, n.d.; Gómez, 2005; Hobson, 2005; León, 2021; Reddy, 2010; Siposova & Carpenter, 2019; Zahavi & Rochat, 2015). These theorists emphasise that there are certain kinds of joint experiences that are "open" or "mutual" in a manner that not all experiences with others are. These joint experiences involve a reciprocity or bidirectionality, with the interaction partners mutually influencing one another (Gómez, 1996, 2005; Reddy, 1996, 2010; Siposova & Carpenter, 2019). Some have suggested that in these engagements, the interaction partner is engaged in a "second person" rather than "third person" manner; as a "you", rather than as a "he", "she", or "it" (Gómez, 1996, 2005; Reddy, 1996, 2010; Siposova & Carpenter, 2019; Zahavi, 2015). It is thus communication that is at the heart of "truly shared" joint attention (Carpenter & Liebal, 2011; Eilan, n.d.; Hobson, 2005; Zahavi & Rochat, 2015). A communicative act can be minimally defined as the intentional production of signal that makes public one's attention to a feature of the world, and is produced in order to draw another's attention to that same feature (Breheny, 2006; Moore, 2017; Sperber & Wilson, 1995). Communication can be said to have occurred when interaction partners each make public (or "mutually manifest"; Sperber & Wilson, 1995) their attention to that feature of the world. This can be achieved by a variety of behavioural means, from an expressive look or verbal utterance (Carpenter & Liebal, 2011). We can call this view the communicative view of joint attention (Eilan, n.d.).

Thus, there is a key sense of the term joint that is worth delineating from other levels, one that places communication at the heart of jointness. This view offers a means of going beyond viewing joint attention as a triangulation of visual attention streams, to one that emphasises the communicative nature of joint experience. On this view, identifying infants' capacity to engage in joint attention is more than examining how two lines of gaze might be coordinated (Hobson & Hobson, 2011; Tomasello, 1995), but on how sharing and communication occurs. Some work has already started to emphasise this dimension of joint attention, attempting to define "sharing looks" that are used to communicatively engage others (Hobson & Hobson, 2007), or examining how infants coordinate smiles and gaze to produce "joint engagement looks" (Jones & Hong, 2001; Striano & Bertin, 2005a; Striano et al., 2009). Whilst there is no widely-accepted means of assessing these early behaviours (Graham et al., 2021; Salo et al., 2018), it is often suggested that these communicative looks are the earliest means by which infants achieve joint attention (Bakeman & Adamson, 1984; Carpenter et al., 1998). It is also important to stress that this perspective goes further than just emphasising the role of positive affect in joint attention, but also emphasises diverse conative and affective dimensions (for example, sharing different kinds of positive or negative "messages") that can be coordinated in communicative engagements (Hobson & Hobson, 2011; Moll et al., 2021).

Furthermore, this approach offers a means of linking joint attention to earlier dyadic engagements. Some research has suggested a link between early dyadic and later triadic engagements. For example, Striano and Rochat (1999) found that infants that produced more social initiations during a dyadic still-face procedure at 7 months also produced more social initiations during triadic tasks at 10 months, suggesting that dyadic and triadic engagements are developmentally associated. Other studies have explored the different kinds of joint engagements that might provide a link between dyadic and triadic engagements, such as by charting infants' transition from more heavily scaffolded "passive joint engagement" to "coordinated joint engagement" (Adamson & Bakeman, 1991; Bakeman & Adamson, 1984). Others have stressed the continuity between dyadic and triadic forms of engagement on conceptual grounds, with each underpinned by a motivation and capacity to engage interactively with others (Eilan, n.d.; Liszkowski & Rüther, 2021; Moll et al., 2021; Reddy, 2005; Tomasello, 1995). However, there is a relative paucity of both empirical and theoretical work that has explored this question, making it an area ripe for further exploration. Finally, viewing joint attention as involving communication implies that it will be developmentally associated with other abilities that also involve communication, such as communicative gestures (Carpenter et al., 1998; Salo et al., 2018) and perhaps some types of imitation (Carpenter & Liebal, 2011; Užgiris, 1984). This view generates testable predictions regarding the development of joint attention and communication, as will be highlighted in the subsequent section.

To summarise, the concept of joint attention was introduced to the literature to highlight the capacity of human infants to coordinate attention with a caregiver to the world around them. The key issue that has divided conceptual discussion is how precisely to articulate this notion of "jointness" (Hobson, 2005). Drawing on recent conceptual work (Siposova & Carpenter, 2019), it was argued that there is a spectrum of cases, but that there is a key sense of jointness which emphasises the central role of communication in establishing a common target of attention as open, mutual or shared.

1.2 The Development of Joint Attention

Just as joint attention has proved challenging to define, so has its development proved challenging to chart. A widespread view is that there is a sudden developmental leap that takes place towards the end of infants' first year, involving a rapid transition from dyadic to triadic engagements. The changes occurring around this time have been described as a "quantum leap" (Stern, 1985) and a "9-month revolution" (Tomasello, 1999), whilst Trevarthen and Hubley (1978) state that "A significant growth transformation of the infant mind at about 9 months has been detected by all who have made adequate biographic observations" (p. 214). They each present a view on which infants are previously not engaged in triadic social engagements involving objects, and become able to do so at around 9-12 months of age. Researchers have struggled to identify how this sudden change might come about, referring to the transition from dyadic engagements to triadic engagements as a "curious developmental gap" (Adamson & Bakeman, 1991).

It is worth noting that a range of researchers have identified important developmental transitions at around 9 to 12 months that are not related to joint attention. Piaget (1954) identified this period as the onset of a new development stage involving "the first actually intelligent behaviour patterns" (p. 210), with the child understanding causal and spatial relations and demonstrating newfound sophistication in their sensorimotor coordination. In the literature on locomotor development, researchers have argued that self-locomotion precipitates dramatic cascading changes in infancy (Anderson et al., 2013; Campos et al., 2000). A final parallel can be drawn with the attachment literature, which has long identified the emergence of stranger anxiety during this age range (Ainsworth et al., 1978). Whilst there is an emphasis on different domains, each argues that there is a rapid transformation in infants' behaviour, cognition and affect that occurs around this time.

However, there have been criticisms of "sudden emergence" views on a number of fronts. Some directly challenge the evidence. Microanalytic investigations of infant-caregiver interactions have examined how gradually changing sensorimotor abilities, combined with differing patterns of caregiver engagement, may account for the emergence of triadic joint attention (de Barbaro et al., 2013; 2016; Rossmanith et al., 2014). For example, de Barbaro and colleagues (2013, 2016) provided evidence that triadic engagements emerge gradually as infants become increasingly capable of decoupling their visual and manual attention. Rossmanith and colleagues (2014) argued that infants, from as young as 3 months of age, are embedded in contexts that are given triadic structure by caregivers, becoming gradually more active participants over time. Striano and colleagues have found evidence that joint attention abilities are present much earlier in development than 9 months, with the ability to initiate (through coordinated gaze and smiles gaze alternation) and follow attention starting to emerge at around 7 months (though as young as 5 months in some infants) (Striano & Bertin, 2005a; Striano et al., 2009).

An additional issue that is closely connected to the gradual versus sudden development debate is whether the developments that occur involve a wholesale shift across a range of social abilities (Bates et al., 1979; Carpenter et al., 1998), or whether specific abilities develop at different rates across different individuals (Racine & Carpendale, 2007; Slaughter & McConnell, 2003; Striano et al., 2009). Some argue that there are subgroups of abilities that pattern together, such as responding to and initiating joint attention (Mundy & Newell, 2007; Salo et al., 2018). It has been typical for those arguing for a sudden change to also argue for wide-ranging relations amongst social abilities, underpinned by a new conceptual grasp of other persons (Tomasello, 1999, 2019), though there is significant diversity across viewpoints and these views do not always neatly align (Moll et al., 2021).

Regardless, a key facet of any developmental account of joint attention is to consider how various joint attention abilities may be related to each other, if they are indeed related.

Despite the debates regarding this developmental period, there are surprisingly few studies that have examined social abilities in the months leading up to 9 months, particularly in comparison to the number of studies with infants from 9 to 12 months and into infants' second year (e.g. Bates et al., 1979; Beuker et al., 2013; Carpenter et al., 1998; Matthews et al., 2012; Salo et al., 2018; Slaughter & McConnell, 2003). Given the range of social, cognitive and motor abilities that are potential relevant to the development of joint attention and communication, a natural focus for further developmental investigate is the period before 9 months (Bakeman & Adamson, 1984; Hoehl & Striano, 2013; Moll et al., 2021).

A further issue is also to establish the processes that precede the emergence of the social abilities that infants start to produce at around 9 months. There is extensive work on the origins of infants' gaze and point following (Bertenthal et al., 2014; Brooks & Meltzoff, 2005; D'Entremont et al., 1997; Moore, 2008; Shepherd, 2010), and the developmental origins of pointing gestures (Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018; Liszkowski & Rüther, 2021; Masataka, 2003; O'Madagain et al., 2019). However, there are few studies exploring the origins of other key social abilities. Few studies considered where other early communicative gestures come from developmentally, and besides the vexed question of neonatal imitation (Meltzoff et al., 2018; Oostenbroek et al., 2016, 2019), there is relatively little work examining early forms of imitation in infants' first year (Barr et al., 1996; Graf et al., 2014; Kaye & Marcus, 1981).

An additional challenge is obtaining large sample, regularly sampled data on the very beginnings of the development of infants' joint attention and communication. There have been a range of efforts to develop tools such as caregiver report questionnaires that provide an insight into early social development, with potential for large samples of infants (Eadie et al., 2010; Fenson et al., 1994; Wetherby & Prizant, 2003). However, these tools have typically focused most heavily on language development, and have not looked in detail at the very beginnings of infants' joint attention and communication. There are thus benefits to developing further tools that can provide insights into the very beginnings of joint attention and communication, generating data that can complement studies that use controlled assessments in a lab, but with larger samples and lower sampling frequency.

As a final but nonetheless important note, it is necessary to highlight that the majority of work in this developmental period has taken place primarily with samples drawn from Western nations (Henrich et al., 2010; Nielsen et al., 2017). Patterns of triadic engagement differ with regard to the modalities employed and the extent to which objects are integrated (Little et al., 2016). Sensorimotor abilities emerge in very different trajectories across different cultures (Karasik et al., 2015), and the appearance of stranger anxiety is not a universal attachment pattern (Keller, 2016, 2018; Quinn & Mageo, 2013). However, some cross-cultural work has suggested that infants in the first year across diverse cultures are equipped with a broadly similar set of joint attention abilities, despite their diverse environmental conditions (Callaghan et al., 2011; Graf et al., 2014; Liszkowski et al., 2012; Salomo & Liszkowski, 2013). Regardless, care must be taken not to universalise the developmental patterns observed in one cultural sample, and that conclusions drawn from a single sample must be formed with an appreciation that different patterns of development may emerge in different social, economic and cultural contexts. This thesis, whilst drawing upon a sample of Western infants, will nonetheless seek to maintain this cross-cultural perspective.

To summarise, different accounts of joint attention explain its development in different ways. One view is that it emerges suddenly at around 9 months (Stern, 1985;

Tomasello, 1999; Trevarthen & Hubley, 1978), while others argue for a more gradual emergence (de Barbaro et al., 2013; Hoehl & Striano, 2013; Rossmanith et al., 2014). Researchers differ regarding the extent to which different joint attention abilities are interrelated, with some finding wide-ranging developmental interrelations (Bates et al., 1979; Carpenter et al., 1998), some arguing for no relations (Racine & Carpendale, 2007; Slaughter & McConnell, 2003; Striano et al., 2009), and others suggesting clusters of related abilities (Mundy & Newell, 2007; Salo et al., 2018). There has been comparatively little work investigating the developments leading up the emergence of early joint attention abilities. It is this issue that this thesis seeks to investigate.

1.3 Investigating the Very Beginnings of Communication and Joint Attention

This introduction began by suggesting that there are definitional and developmental questions that remain in the study of joint attention, and that these issues are inextricably linked. Definitionally, there has been a growing focus on emphasising the communicative core of joint attention in explaining its jointness. Developmentally, questions remain about when and how joint attention emerges in development, and its relation to early social and other abilities.

This thesis aims to address both sets of questions by investigating the very beginnings of joint attention and communication. There is a need for further empirical evidence and conceptual clarity regarding the very beginnings of joint attention abilities, and the processes that lead up to their emergence. The thesis is based on a comprehensive, longitudinal study of infants between the ages of 6 to 10 months, following them for 5 monthly sessions (as well as collecting follow-up questionnaire data at 11 and 12 months). It presents new methods, data and conceptual work that aims to address a set of salient questions that will help contribute to the larger issues of understanding what joint attention is and how it develops.

After outlining the study's method in Chapter 2, the first question the thesis seeks to address is: When and how does infants' capacity to communicatively initiate joint attention develop? As Chapter 3 explores, this question is of substantial significance to debates over joint attention's definition and development. Chapter 3 presents a novel approach to eliciting and coding "joint attention looks"; the coordination of gaze from a stimulus to an adult with concurrent communicative facial expressions and/or vocalisations in order to comment on some stimulus.

The second question the thesis seeks to address is: When and how do infants' earliest communicative gestures emerge? As some of the earliest means by which infants engage in joint attention, communicative gestures are a key behaviour to examine when investigating the origins of joint attention. This issue is addressed in Chapter 4, which charts the emergence of a range of different communicative gesture types. In addition, this chapter explores an important but relatively underexplored issue: the developmental processes that precede the emergence of some of infants' earliest conventional communicative gestures.

The third question the thesis seeks to address is: How do early joint attention and communication abilities relate to each other, and to other relevant developments that are occurring between 6 and 12 months? These issues are addressed in Chapters 5 and 6. First, Chapter 5 examines the further social, cognitive and motor abilities that were assessed in the study, focusing on their emergence and development. Then, Chapter 6 draws together the data from the preceding chapters to explore the emergence of all the assessed abilities, their developmental trajectory, and relations amongst them.

The fourth and final question the thesis seeks to address is: How do caregivers assess early communicative development, and how do their assessments of communicative development relate to researchers' assessments? If researchers can obtain reliable and consistent reports from caregivers regarding early communicative and other behaviours, it would provide an important new source of data to help elucidate the development of joint attention and communication, as well as other abilities. Chapter 7 thus reports on maternal assessments of early social and motor behaviours and explores how these reports relate to researcher assessments of the same infants.

After addressing these questions in Chapters 3 to 7, the findings are drawn together in the conclusion, Chapter 8. Returning to the intertwined questions of the definition and development of joint attention, the conclusion will reflect on some of the big-picture conceptual issues that emerged over the course of the thesis, as well as offering suggestions as to how future work can build on its findings.

CHAPTER 2

OVERALL STUDY DESIGN AND METHOD

This chapter details the participants, method and overall analytic strategy used in the project to provide the reader with an overall sense of the study design and methods. Further details of tasks, including the procedure, coding and results, are detailed in the subsequent chapters.

2.1 Participants

Infants were recruited through online advertisements, in-person connections at local groups and activities, and through a support group that met in the University of St Andrews Baby and Child lab (see Salter et al., 2021). In total, 25 mother and infant dyads participated (14 female infants, 11 male infants). Of the 23 infants whose mothers provided information about educational background, 20 had at least one parent who had completed tertiary education, and the remaining 3 had at least one parent who had completed secondary education. No data on ethnicity were collected, but all mothers were fluent English speakers. Of the infants that participated, 13 out of 25 were firstborn. Ethical approval was obtained through the University of St Andrews School of Psychology and Neuroscience Ethics Committee, and all mothers gave informed consent for their and their infant's participation.

Participants participated in 5 monthly sessions from when they were 6 months old to when they were 10 months old. Each session normally took place within a week either side of the infant turning that number of months. However, in 2 cases, the session took place 10 days after the infants' birthday, and in one additional case, a session was not completed at the initial visit but was rescheduled and completed within a week. Only one session was missed entirely (at 10 months).

2.2 Materials and Set-up

All testing took place in the University of St Andrews Baby and Child Lab.[1] The majority of tasks took place within one testing room, depicted in Figure 2.1. In the room were a pair of soft play mats attached to the floor. On each side of the room were two small chairs, on which stimuli for two of the tasks (gaze and point following; see Chapter 5, section 5.1.2) were placed. During the task period of the session (discussed in section 2.3.3), the infant sat in a small infant chair with an attached tray, placed at one end of the play mats. The experimenter (E) sat on the opposite side of the mats facing the infant. The small chair raised infants to be approximately eye-level with E while he was seated. The chair had an attached tray on which toys could be placed. There was also a table that could be slid over the top of the tray. The table was placed to the side for tasks such as the joint attention tasks (see Chapter 3), and was placed behind E and to the left when it was not needed for a task. If the infant was struggling to sit unsupported, a folded towel was used to provide support to the infant's hips and trunk. If the infant was on the mother's lap, mothers were informed about their role in each task before each task began; for example, when to not attend to the task or what to expect from the task.

Two cameras were placed at opposite corners of the room, one facing infants head-on and one to the side of the infants' seat. This enabled full capture of the free play period, and enabled front and side views of the infant during the task period. In another corner, behind and to the right-hand side of E, a chair was placed in which the mothers sat during the task period. This positioning was chosen so that they remained within view of the infant.

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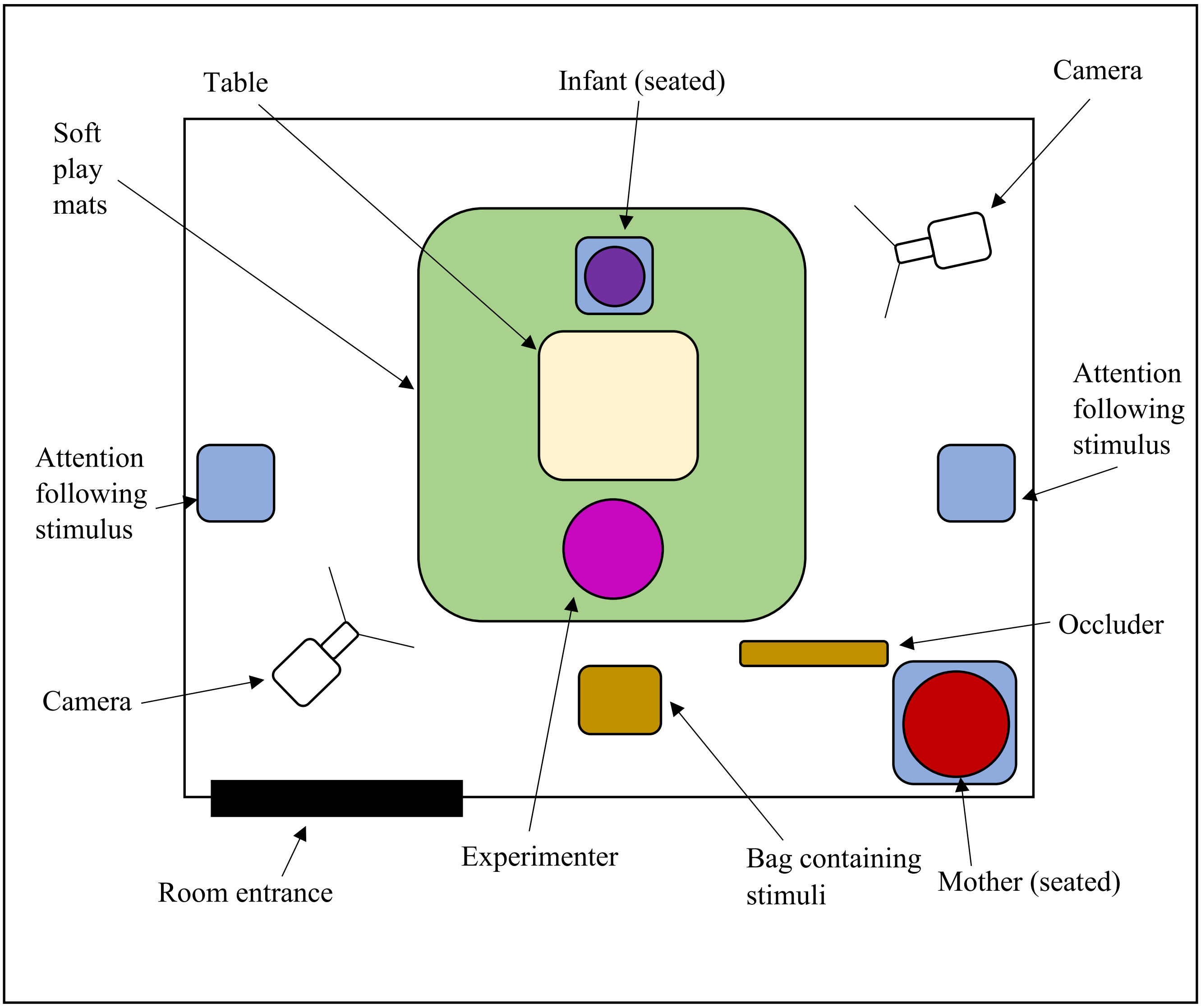
[1] Three of the sessions took place in a different room due to building closure. The layout was preserved as much as possible, and extra time was provided to allow the infants to accommodate to the new space. The "Decorated Room" portion (2.3.5) was not completed at these sessions because no comparable set up could be created.

To ensure that the infant was not distracted by any activity outside the testing room, the small windows on the room door were covered. Small viewing holes were made in the covers to enable E to monitor what was happening in the room at those times that the mother and infant were left alone in the room.

Figure 2.1

Layout of Main Testing Room



Note. The table was placed on E's left-hand side when not in use.

The decorated room task and the interview portion of the study took place in another, larger room, divided into two sections by an occluding barrier.

To provide for mothers with an older child, a research assistant looked after the sibling in an adjoining room.

2.3 Procedure

Upon arrival to the lab, mothers and infants first had a few minutes to accommodate to the space and to chat with E. At the first session, the mother provided informed consent for her and her infant to participate in the entire study. When both mother and infant were settled, had provided consent, and were ready to start, the free play period began.

2.3.2 Free-play Period

The sessions began with the free play period. Mothers were asked if their infants were able to sit unsupported for extended period. If they said no, they were asked to place their infants in a “Bumbo” soft support seat. If the infants used the Bumbo, the Free-play period was split into two 3-minute blocks. The infant remained in the Bumbo for the first block, though with the option for the mother to take them out of it if they were showing discomfort. After 3 minutes, E entered and asked the mothers to remove the infants from the Bumbo and carry on playing for another 3 minutes, with the infant placed in whatever position was comfortable. The Bumbo was used to ensure that all participants at all sessions at least began with the same spatial layout: face-to-face with a short distance of spatial separation from their mother. If the infant could sit confidently (as judged by the mother), the Bumbo was not used, and mother and infant played together for 6 uninterrupted minutes. In these cases, mothers and infants were initially arranged in the same face-to-face configuration, but they were told they could move freely as long as they remained on the mat, in view of the cameras. Mothers were asked to play with their infants as they typically would, and were informed that they were free to use whichever toys of those provided that they wanted to in whatever ways they wanted.

2.3.3 Task Period

Once the free play period concluded, E entered and the task period began. The structure of the tasks used can be seen in Table 2.1. The bulk of the tasks, in which the infant sat in the chair opposite E, took place between two show elicitation tasks, as these tasks required assistance from the mother. The details of the show elicitation tasks are discussed in Chapter 4. Once the first show elicitation trial was complete, the mother placed the infant in the small chair at the end of the mats (see Figure 2.1), and E sat on the opposite side of the mat, at which point the other tasks started.

To avoid having similar tasks delivered back-to-back, the tasks were split into two blocks. Each block's task order was pseudo-randomised. Across blocks, the majority of tasks were "paired" with a conceptually similar task (e.g., dyadic and triadic imitation; full pairings in Table 2.1). At the halfway point, between each block, the same activity (building and knocking over a tower of cups) was performed. This activity was initially included as a task, but after piloting it was decided that this activity would serve only as a break between blocks (meaning that if Block 1 ended with a task that was paired with the first task in Block 2, then these tasks were still not one after the other).

Table 2.1

Order of Activities within Session

Welcome	
Free play	
Show elicitation task (first condition)	
Tasks: Block 1 (Order pseudo-randomised within block)	Triadic imitation, point following, gaze following, joint attention (interesting noise), social assistance, means-ends, object permanence.
Cup stacking activity (not paired)	
Tasks: Block 2 (Order pseudo-randomised within block)	Dyadic imitation, point following, gaze following, joint attention (interesting sight), joint attention (moving toy), social reach, give elicitation
Show elicitation task (second condition)	
Point elicitation (decorated room)	
Interview	
Session conclusion	

Though the order was predetermined, E had some flexibility. For example, E was sometimes unable to establish eye contact (a necessity in the attention following and imitation procedures) and thus moved onto another task before returning to the missed task. In other situations, the infant did not pick up the toy (a necessity for the give elicitation task). If so, E moved on to another task before trying the give elicitation task again. If these changes were made, E still ensured that similar tasks did not immediately precede or follow one another. If this was unavoidable (e.g. if the final 2 tasks left were gaze and point following), E played with the infant for 30 seconds between tasks, to ensure a break between similar tasks.

The tasks used were conceptually identical but had differing stimuli, as a means of minimising potential learning effects. For example, for triadic imitation, 5 different stimuli were used that assessed the ability to imitate an action on an object, and for gaze and point following there were different toys as targets at each session. Inevitably, there were subtle differences across these stimuli, such as the motor demands or individual differences in interest in the stimuli. However, the extent of the influence of these differences was thought to be sufficiently small that important developments were still not obscured.

All stimuli were thus organised into 5 sets, and the order in which the infants received the sets was randomised for each participant. For the free play, mothers were given a bag containing an assortment of different toys, with a combination of soft toys and plastic toys, with some being noise-making and others not. An example stimuli set can be found in Appendix 2A.

Whilst the infant and E were engaged in the tasks, the mother sat in the chair behind E to his right. She was provided with either a questionnaire or the list of interview questions, and was asked to try not to catch her infant's attention or to interact with the infant while the tasks were ongoing. However, the mother was informed that if she detected that her infant was experiencing discomfort in any way, she was welcome to interrupt proceedings at any point. In some cases, the infant remained upset as long his/her mother was not close. In such cases, the mother was allowed to sit just behind the infant on the infant's left-hand side. If the infant remained upset, he/she performed the tasks while sitting on his/her mother's lap.

E also sought to be attentive to possible signs of distress in the infant; if he was not certain, he erred on the side of interrupting the tasks to ask the mother. If the infant was upset, they were given as much time as needed to calm down, be fed or be changed. In some cases, the task portion was interrupted and participants proceeded with the decorated room task (see section 2.3.6). This task served as a change of scene (it took place in a different room) and provided time in which the infant was with his/her mother. Often, the infant was happy to proceed with the task portion after this interlude. In other cases, the interview was conducted as a break from the task portion, for similar reasons; the infant could be with their mother for an extended period.

2.3.4 Maternal Activity during the Task Period

If the infant was content to proceed with the tasks, the mother completed a questionnaire or provide written interview responses, depending on the session (Table 2.2 lists the activity for each session). Interview responses were written by hand and used to guide and facilitate the later interview period. Questionnaires were either completed by hand or on a laptop, depending on the questionnaire. If the mother sat with the infant, the questionnaires were either finished during the session, taken home or abandoned. This decision was made based on what the mother was willing and able to complete. Further questionnaires were also sent to mothers at 11 and 12 months. All but one of the mothers completed at least some of the 11-month questionnaire, and completed at least some of the 12-month questionnaire.

Details of the interview questions are discussed in Chapter 7. Two established questionnaires were used at other points in the procedure. At 6 and 10 months, mothers completed the Infant Behaviour Questionnaire, Revised Version (IBQ-R) (Putnam et al., 2014), which provides a measure of infant personality. At 8 and 12 months, mothers completed the UK Communicative Development Inventory (UK-CDI; Alcock et al., 2020). The UK-CDI provides a measure of infant language production and comprehension, as well as providing caregiver reports of other communicative behaviours such as gestures (see Chapter 7).

Participants were also contacted halfway between monthly sessions to respond to questions for the interview portion of the study. This was either conducted through telephone calls or via online completion of the questions using Qualtrics (Qualtrics, 2020). Further interview questions (and, at 12 months, the UK-CDI) were also sent via Qualtrics at 11 and 12 months. Details of the monthly questions and questionnaires provided are listed in Table 2.2.

Table 2.2

Questionnaires or Interview Questions Provided at Each Month

Age	Activity
6 months	IBQ-R, interview questions
7 months	Interview questions
8 months	UK-CDI, interview questions
9 months	Interview questions
10 months	IBQ-R, interview questions
11 months	Interview questions (unique set)
12 months	Interview questions (unique set); UK-CDI

2.3.5 Decorated room

Once the experimental tasks had finished, the mother and infant moved next door for the Decorated Room task. This task was an adaptation of the procedure developed by Liszkowski and Tomasello (2011). In the room, a number of interesting sights were arranged (see Appendix 2A, Figure 2A12). The same sights were used for each session, in the same arrangement. They were designed to be engaging in a variety of ways. For example, there were visually interesting sights (a mirror, brightly coloured pom-poms), moving objects (a fan with streamers) and tactilely interesting objects (e.g. a large soft teddy bear). The aim of the task was to elicit communicative gestures from the infants.

The mother was asked to carry the infant. We did not specify how she ought to do so, as we wanted this to be as natural as possible. She was asked to stand in a particular location, where they were distant from the stimuli, and was asked at the start of the trial to remain in that location and wait for her infant to convey his/her interest in the stimuli. She was told that if her infant told her where to go (e.g., by gesturing), she should take him/her there. The mother was told that if, after waiting for a while, the infant had shown no interest or did not indicate where to go, she could move closer to the toys, eventually bringing the infant to the objects. No time period was specified for how long caregivers should wait, as we did not want to risk placing a limit that would mean potential gestures might be missed. Unlike the procedure in Liszkowski and Tomasello (2011), we allowed infants to directly interact with the objects, in order to minimise their frustration and subsequent drop-out rate. However, mothers were told that after 10-20 seconds of interaction with an object, they should return to the starting location. This task lasted 4 minutes.

2.3.6 Interview

Once all the tasks were complete, or if a break was needed from the tasks, the Interview period began. E, the mother and the infant were seated in the interview room. The interview used a semi-structured approach, with the same set of questions (see Appendix 7A) being asked at each session, but with E able to ask relevant follow-up questions. The order of the questions was not fixed. The procedure in the second and fourth sessions differed slightly from the others, as mothers had the opportunity to write their responses during the tasks because there were no questionnaires to complete at those months. In the interview period, E chose either to follow up on the written responses, or skip them (for example, if they were sufficiently comprehensive or clearly negative regarding the production of a particular behaviour).

Mothers were informed that, as with the rest of the session, they could interrupt (e.g. to feed or change their infant) or end the interview for any reason, meaning that if the infant was upset then they did not have to continue. If the interview was not conducted or not complete, mothers were asked to respond to the questions online via Qualtrics. Overall, the aim was to be methodologically flexible, respecting the time and preferences of the participating mothers and infants.

2.3.7 Session Conclusion

After the interview was complete, the session ended. Each session took between 50 to 90 minutes. At the end of each session, the participants were recompensed for their participation, receiving gifts including a baby book (one at each session), lab-themed onesie (at the 8-month session) and a certificate (at the 10-month session). Mothers were also sent the video recordings of the free play periods from each month. At the final session, participants received a debrief form explaining the purpose of the research, and had the further opportunity to ask any questions about the project.

As a summary, Table 2.3 details the various data types that were collected, and the ages at which these data were collected.

Table 2.3

Data Types Collected Across Study

Study element	Age of participant (months)	Collection methods	Data type
Free-play	6, 7, 8, 9, 10	Observation	Video data for behavioural coding
Task period	6, 7, 8, 9, 10	Behavioural tasks	Video data for behavioural coding
Interview	6, 6.5*, 7, 7.5*, 8, 8.5*, 9, 9.5*, 10, 11**, 12**	Interview (in person or by telephone); written responses (by hand or via online form)	Video data for transcription; notes recorded by E from phone conversations; written data from sheets or online forms.
Questionnaires	6, 8**, 10, 12**	Written responses (by hand or via online form)	Written data from sheets or online forms

Note. *Data collected by phone interview or online survey. **Data collected by online survey.

2.4 Coding and Analytic Strategy

Since each chapter uses different analytic methods, much of the detail will be explained within the upcoming chapters. However, some general strategic decisions regarding the analytic approach are helpful to outline here.

2.4.1 Behavioural Coding Strategy

For every task, a conceptually consistent coding approach was taken. A three-level scheme was used for each task, with scores being either “0”, “1” or “2”. Broadly, the scores mapped on to the following conceptual framework:

2: A clear, intentional, recognisable instance of the target behaviour.

1: An attempt at the target behaviour, a partial instance of the behaviour, or otherwise relevant behaviour that involves features of the target behaviour but is missing (a) key component(s). This code accounts for behaviours that may possibly be considered a candidate instance of the behaviour of interest, but cannot be confidently assigned as such.

0: No production of the target behaviour.

Depending on the task and the behaviour being investigated, the details of the schemes differ. However, all coding schemes map onto this conceptual organisation, in order to enable systematic comparisons between scores. The respective schemes will be discussed in more detail in the subsequent chapters, and the full coding schemes can be found in Appendices 3B, 4A, 5A and 7A.

The inclusion of the scores of “1” were not part of the initial design. Rather, over the course of the study and through watching the video recordings, it appeared that there relevant behaviours that did not qualify as mature, conventional instances but appeared relevant and possibly related to the mature forms. We wanted to use highly conservative coding when reporting mature or conventional instances of behaviours, but did not want to miss other possibly relevant behaviours that were occurring. Thus, the inclusion of the "1" category was generally exploratory; we did not know when and whether we would see instances of the "1" score. Since the analyses that involve the "1" scores generally focus on whether these incipient and partial behaviours are present or not, and if so, whether they occur consistently before "2" scores, we do not explore the frequency of their production.

2.4.2 Inter-rater Reliability

All scores from the free play, behavioural tasks and interviews were assessed for reliability in the same manner. The initial coding (100%, besides a few select cases; see Appendix 2B) was conducted by the author of the thesis (coder 1). A second coder (coder 2; not the same coder for every task) who was naïve to the hypotheses was trained in the application of the coding scheme by coder 1. Training involved discussion of the scheme and of relevant behaviours produced by pilot participants. Once coder 2 was trained, they scored the tasks independently. For the behavioural tasks, 100% of the dataset was coded. For the free play, a randomly-selected 33% of the sessions were coded due to the length of time involved. Reliability scores were calculated using the kappa2 function in R, part of the irr package (Gamer et al., 2019). This function calculates Cohen's Kappa coefficient, and allows for weighted calculations. Squared weighting was used, where disagreements are weighted according to their squared distance from identical agreement, ensuring a heavier penalty for greater disagreements (i.e. between "0" and "2") than for smaller disagreements (between "0" and "1", and "1" and "2").

There is no non-arbitrary criterion for determining acceptable κ scores (Sim & Wright, 2005), but we used a threshold of 0.7κ which is widely considered a substantial level of agreement (Altman, 1990; Landis & Koch, 1977). If the initial inter-rater reliability coding produced a κ of less than 0.7, coder 1 and coder 2 discussed disagreements in the application of the scheme, without referring to specific examples, and inter-rater reliability was checked again. In almost all cases, reliability scores reached the threshold of 0.7 after the reassessment, and the final range of κ scores was from 0.71 to 0.9. In the three cases (showing task scores, pointing scores, interview coding of joint attention looks) in which the revised scores still did not achieve this threshold, a third resolving coder was used to determine the scores for cases in which coders 1 and 2 differed. All κ scores can be found in Appendix 2B.

2.4.3 Addressing the Analytic Challenges of a Longitudinal Dataset

Longitudinal datasets have unique challenges that must be met to ensure that the data are analysed appropriately. Here, we detail some of the analytic challenges and the decisions made regarding how these challenges were addressed. As with the rest of the chapter, the aim is to provide an overall introduction; other, more specific details are addressed in subsequent chapters.

2.4.3.1 Outcome Variables

Often (see Chapters 3, 4 and 7) analyses with binary outcomes ("presence" or "absence" of a skill) are used. Dichotomised or categorical outcomes can limit the analytic options available, and risk skewing results by assuming that all instances of "presence" involve equal rates of production on the part of the participant. However, the appropriateness of outcome variables is ultimately dependent on the kinds of questions one is interested in addressing, and for many of the questions this study was designed to address, dichotomous or categorical outcomes were most appropriate.

Since we wanted to examine a range of abilities within as short a period as possible (to minimise the amount of time the infants were expected to be attentive) we used brief tasks designed to elicit single instances of target behaviours. Thus, using binary outcomes was fitting for the types of tasks used. Furthermore, since the study was designed to capture the very beginnings of social and communicative abilities, we did not expect high frequencies for all of the target behaviours. In such cases, dichotomised outcomes are often more appropriate (Salo et al., 2018). Finally, use of dichotomised outcome variables facilitated more straightforward comparison across the free play and tasks. In a free play period, an infant might have opportunities to produce a behaviour multiple times, whereas tasks were much briefer. In such a case, comparing the frequencies of a behaviour could skew the results.

2.4.3.2 Modelling Longitudinal Data

At several points in the thesis, Generalised Linear Mixed Models (GLMMs) are used to model the data. In the analysis of longitudinal data, mixed models have various advantages over other methods of analysis. Methods such as Repeated Measures ANOVA (rmANOVA) require equal numbers of assessments with equal temporal spacing. They also have limited options for dealing with missing data (Krueger & Tian, 2004). Most significantly for the present study, methods like rmANOVA cannot model non-continuous data and ignore autocorrelative effects (Raadt, 2019). That is, for a longitudinal rmAVONA, the model does not respect the fact that a participant's score in a task at age n is influenced by their score at age $n - x$ and subsequently influences their score at time $n + x$, where x is some period of time.

GLMMs can effectively model longitudinal data because they are capable of dealing with hierarchical data, that is, data for which there are principled reasons to cluster different measurements together. For example, it may be beneficial to cluster patient data by the hospital from which it was collected, to examine whether the hospital site influenced the results. For the analysis of longitudinal data, GLMMs treat each individual as a cluster, providing a means of linking repeated measures to the same participant and thus accounting for intra-individual correlations of outcome scores over time, as well as inter-individual differences (across clusters; Krueger & Tian, 2004). GLMMs account not only for the error (the difference between the recorded values and the true values) of each response, but also the error of each cluster. This more complex error structure is not necessarily optimal for every dataset. It is possible to conduct a Generalised Linear Model (GLM) in which each participant is entered as a factor. This accounts for autocorrelation with participant scores but uses a simpler error structure (i.e., only accounts for the error of each response). The downside is that it requires using large number of variables in the model, which is likely to influence model fit.

To statistically assess which model was most appropriate in each case, we compared the GLMM with a GLM to provide a more objective index of appropriate model selection. Model fit was assessed using the Akaike Information Criterion (AIC), a measure of model fit that accounts for both under- and over-fitting (Akaike, 1973). Comparisons were conducted using the model.sel function MuMIn package in R (Bartoń, 2015), and tables displaying these comparisons can be found in Appendices 3D, 4C, 5C and 7C.

All analyses were conducted in R using R Studio (R Core Team, 2013; RStudio Team, 2020) using the R package lme4 (Bates et al., 2015). We used the package emmeans (Lenth et al., 2018) to conduct Tukey's Honest Significant Difference (HSD) post hoc tests, which allowed for comparisons of mean values of the scores while accounting for the effects of multiple comparisons on the *p* values obtained. The package sjPlot (Lüdecke, 2021) was used to generate tables of model coefficients for the GLMMs. Charts were created using the functions ggplot2 (Wickham, 2016), ggpubr (Kassambara, 2020) and reshape2 (Wickham, 2020).

2.4.3.2 Censoring

At several points in this thesis, we ask *whether* and *when* various abilities emerge in the period of development investigated in this study (see Chapter 6, Chapter 7). By addressing issues of event occurrence, we run into the challenge of *censoring* (Leung et al., 1997). Censored data occurs when the event of interest (e.g. the onset of a behaviour) occurs outside the bounds of the period of examination of a study. This can either be because the event has already taken place prior to the study start ("left-censoring") or because the event first takes place after the study, or never occurs ("right-censoring"). Censoring is an unavoidable issue when examining the occurrence of events over time (Singer & Willett, 2003). To try to deal with censoring, a wide enough age range is needed to try to capture the emergence of different abilities.

Various steps were taken to try to offset the issues of censoring, whilst recognising that it is virtually impossible to fully eliminate (Singer & Willett, 2003). These steps were taken both in the overall design of the study, as well as the kinds of questions posed and analyses employed. In terms of the study design, we tried to eliminate "left-censoring" as much as feasibly possible. This meant choosing a starting age that, guided by previous work, was sufficiently early that the vast majority of infants would likely not succeed in the tasks used. We thus started at 6 months of age. The only ability that we did predict would potentially be present before 6 months was independent sitting, but since this ability was not of critical importance to the study, we compromised on this ability rather than try to expand the age range further. In some cases, abilities emerged earlier than we predicted (see Chapter 3), creating left-censored data, but this was overall relatively rare. We tried to deal with right-censored data for certain abilities through the follow-up questionnaires when infants were 11 and 12 months old. Whilst not providing the same fidelity as directly-observed data, these data provided a means of addressing age-of-emergence questions beyond the original range of observation (see Chapters 4 and 6).

Various analytic choices were made to minimise the impact of censoring. First, we sought to ensure that the hypotheses that we put forward could still be meaningfully addressed even in the presence of censored data. In some cases (Chapter 6) we used analytic tools explicitly developed to assess event occurrence data such as survival analysis (Kleinbaum & Klein, 2010). In other cases only the ordering of emergence of the various abilities is investigated (e.g. Chapter 4). When relations between ages of onsets of different abilities were examined (e.g. Chapter 6), the approach to censored data is to be transparent about how it is addressed. This means being clear on any assumptions that are made in the analysis, or being clear when censored data is dropped from the analysis. In some cases, we present different analyses of the same data that deal with censored data in different ways.

2.5 Summary

This chapter has provided information about the participants, as well as an overview of the testing procedure, data collected and analytic strategy. The coming chapters will focus on the specific tasks, providing more detailed information about the methods used, coding procedures, results and discussion for the different elements of the study.

CHAPTER 3

THE DEVELOPMENT OF JOINT ATTENTION LOOKS

When are infants first capable of engaging in joint attention? Addressing this question requires both a clear conceptual view of what constitutes a capacity to engage in joint attention, and a developmental account of how this capacity develops. The standard account of the development of joint attention is that infants are first capable of dyadic engagements from around 2 months of age (Bateson, 1975; Brazelton et al., 1975; Trevarthen & Aitken, 2001). At around 9 months of age, they transition to triadic engagements involving another person and some object or event (Tomasello, 1995; Trevarthen & Hubley, 1978). From this age, infants take on a newly active social role, increasingly initiating social engagements (Cohn & Tronick, 1987), and beginning to engage in social behaviours such as imitation and gestural communication (Bates et al. 1979; Carpenter et al., 1998). On one influential account, these developments occur suddenly at around 9 months in what has been called the "9-month revolution" (Tomasello, 1999, p.61).

A number of researchers have questioned this canonical story. Work led by Striano and colleagues have argued that infants have a sensitivity to triadic social situations (Parise et al., 2008; Striano & Stahl, 2005; Striano et al., 2007) prior to 9 months, with triadic joint attention skills such as attention coordination and attention following emerging prior to 9 months (Striano & Bertin, 2005a, 2005b; Striano, Stahl, & Cleveland, 2009). In addition, there are relations between dyadic social behaviours and triadic behaviours (Striano & Rochat, 1999), suggesting that triadic engagements have their roots in earlier dyadic exchanges. In a similar vein, micro-analytic methods that focus on moment-to-moment affective and sensorimotor coordination have been used to chart infants' participation in increasingly complex activities that also suggest a gradual process of expansion from dyadic to triadic engagements (de Barbaro et al., 2013; de Barbaro et al., 2016; Rossmanith, et al., 2014).

Part of the challenge of disentangling developmental accounts is that different conceptions of joint attention are applied (Carpenter & Call, 2013). Particularly important to clarify is the notion of the “jointness” of joint attention (Hobson, 2005); how ought situations where two persons are merely simultaneously attending to a common locus be differentiated from situations in which both co-attenders are aware that the target is shared by both co-attenders (Siposova & Carpenter, 2019)? Recent theoretical work has argued for the key role of communication and second-person engagement in achieving the jointness of joint attention (Carpenter & Liebal, 2011; Eilan, forthcoming; Gomez, 1996; León, 2021; Moore & Barresi, 2017; Reddy, 2010; Siposova & Carpenter, 2019). To truly achieve the openness and mutuality characteristic of joint attention, there needs to be active sharing of the common attentional focus through communication. Only when there is active sharing and communication is the mutuality, bi-directional influence and openness of joint attention achieved (Carpenter & Liebal, 2011; Siposova & Carpenter, 2019). Whilst gestures such as showing and pointing can establish joint attention, it has been suggested that the simplest forms of communication can be achieved through the coordination of behaviours such as a look and a smile in response to some stimulus (Jones & Hong, 2001; Jones et al., 1991; Striano & Bertin, 2005a; Venezia-Parlade et al., 2009; Venezia et al., 2004).

It has been argued that this kind of behavioural coordination provides important evidence of a capacity to engage in joint attention (Carpenter & Liebal, 2011; Hobson, 2005). It is a key source of evidence as it demonstrates that infants are themselves capable of actively initiating joint attention to a target. Behaviours such as the alternation of gaze between a person and an object are not sufficient to be confident that an infant is indeed initiating joint attention (Carpenter & Liebal, 2011; Tomasello, 1995). For instance, an infant might alternate gaze from an object to an agent to check that the agent is still present. Thus, it has been argued that what is needed is some way of assessing the "quality" of infant looks, to consistently identify when looks are used to initiate joint attention and when they are serving other functions (Graham et al., 2021; Hobson, 2005).

One such attempt to categorise different kinds of looks comes from Hobson and Hobson (2007). They proposed delineating between "orienting", "checking" and "sharing" looks. On Hobson and Hobson's definition, an orienting look is a prepotent response to some stimulus, a checking look is produced in order to monitor another's presence or response, and a sharing look conveys personal involvement and emotional contact. However, recent work by Graham and colleagues (2021) has shown that these broad categories are insufficiently specific for the purpose of behavioural coding. Instead, they suggest that there is a need to identify information on a range of behaviours and how they are coordinated.

Previous work has sought to identify the coordination of multiple behaviours in the initiation of joint attention, particularly the coordination of looks and smiles. Striano and colleagues have examined "joint engagement looks with smile" (Striano & Bertin, 2005a), behavioural sequences in which the infant looks from a stimulus to a caregiver with a smile, and this smile is not produced solely in response to some action by the caregiver. Previous work has also examined infants' "anticipatory smiles" (Jones & Hong, 2001; Jones et al., 1991; Venezia-Parlade et al., 2009; Venezia et al., 2004), cases where the onset of an infant's smile begin prior to their look towards a caregiver. This behaviour appears from as young as 8 months of age. The temporal coordination of smiling and gazing indicate that the smile is not simply a response to the caregiver's face. Whilst prior work has focused on smiles, it is also important to recognise other simple behaviours that can be coordinated with a look, including non-smile facial expressions and vocalisations (Carpenter & Liebal, 2011; Messinger, 2002; Wu & Gros-Louis, 2014). For this reason, this study will give these looks the more general term “joint attention looks”, rather than focusing solely on smiles or “sharing” looks (Hobson & Hobson, 2007).

Joint attention looks are communicative behaviours, serving as a simple means of commenting on some referent (Bruner, 1975; Carpenter & Liebal, 2011) and making it clear that the look is about a particular stimulus (Messinger & Fogel, 2007; Venezia et al., 2004). They are referential, being about some target in the world. They are produced to draw another’s attention to a common target such that both agents become mutually aware of that target, or are produced to establish mutual awareness that another is attending to the same target as oneself when co-attenders are already attending to the same target (Carpenter & Liebal, 2011). In this sense, these behaviours play a similar role to gestures in terms of the role they play in establishing shared referents (even if later communicative gestures like showing and pointing are more effective at individuating specific referents; Mundy et al., 1995; Salo et al., 2018).

This kind of behavioural coordination is also relevant to the developmental transition from dyadic to triadic engagements; it is plausible that the communicative capacity that manifests in early dyadic exchanges is later expressed in later triadic engagements (Moll et al., 2021; Reddy, 2010; Striano & Rochat, 1999). Thus, these behaviours also offer a means of linking early dyadic exchanges with later triadic forms of engagement. Similarly, it is not clear whether these kind of communicative looks are preceded by other kinds of non-communicative looking behaviour that have a triadic structure, such as social referencing or checking looks (Hobson & Hobson, 2007).

This prior work provides a promising direction for assessing behavioural evidence of joint engagements. However, these studies have focused on examining free play engagements involving infants and caregivers, rather than using experimental methods that seek to elicit relevant behaviours without the social scaffolding provided by caregivers. While there are studies examining social referencing that use controlled activation of stimuli (Striano & Rochat, 2000), and methods that effectively elicit gestures like declarative pointing (Liszkowski et al., 2004; Liszkowski & Tomasello, 2011), no such methods have been developed that focus specifically on the elicitation of joint attention looks. This is not surprising given the lack of a consensus on how to identify infants' attempts to initiate joint attention through looking behaviour. However, it is an important and underexplored area given the conceptual and developmental debates regarding the very beginnings of infants' capacity to engage in joint attention.

The present study addresses this gap by providing longitudinal data from 6 to 10 months using both experimental and free play methods. It also provides a new coding approach that views joint attention looks as communicative behaviours that involve active sharing of a target stimulus. This approach both complements and expands upon previous research (e.g., Jones & Hong, 2001; Striano & Bertin, 2005a; Venezia et al., 2004) by focusing on the coordination of multiple behaviours (Graham et al., 2021). A new experimental paradigm is introduced that is designed to effectively elicit joint attention looks. These involved repeatedly activating some stimulus (interesting sight, interesting sound or moving object) out of sight of an experimenter (E) but in sight of the infant, in order to encourage the infant to share that sight through joint attention looks.

Using these paradigms in a longitudinal design, this study aimed to provide new evidence for the developmental emergence of joint attention looks. In particular, our aim was to examine if there was a sudden increase in infants producing joint attention looks, which we examined by assessing for a significant increase in infants producing joint attention looks between consecutive sessions. Behaviours were assessed using a three-level scheme, focusing not only on joint attention looks (scores of "2") but also on non-communicative looks (scores of “1”). Our hypothesis was that infants would be capable of looking from a stimulus to an agent prior to being able to coordinate other concurrent behaviours with that look. It also aimed to compare infants’ performance in experimental tests with performance in free play to assess whether there are differences in production in these contexts, both comparing overall performance in the tasks as well as performance in each task type. Our hypothesis was that infants would be more likely to produce joint attention looks in the experimental tests than in free play. Finally, the consistency of infants’ performance was assessed by examining changes in the number of different tasks in which infants produced joint attention looks. Our hypothesis was that infants would produce joint attention looks with increasing consistency as they aged.

3.2 Method

3.1.1 Procedure

Three novel tasks were included that sought to elicit initiations of joint attention behaviours, along with a 6-minute free play between infants and mothers (M) outlined in Chapter 2, section 2.3.2.

3.1.1.1 Interesting Sight Task

The stimulus was a set of LED lights placed inside a translucent blue plastic box, activated by remote control (Appendix 3A, Figure 3A1). A different pattern of flashing was used at each session. The box was initially positioned behind E so the infants could not view it. To start, the table was positioned on the left-hand side of E. When the task was to start, E gave the infants a toy as a distraction, before placing an occluding barrier on the table. E then placed the lights on top of the table, with the barrier obscuring the infants’ view of the lights. E then took away the toy from the infants, before quickly removing the occluder whilst simultaneous activating the lights. E then sat facing the infants, with the remote control hidden behind his back. E activated the lights three times in total per trial. When the lights were on, E waited until the infants looked at the lights and then left the lights on for 5 seconds. This was to ensure that the infants had seen the stimulus. After these 5 seconds, the lights were turned off for 5 seconds. If at any point the infants made eye contact with E, E said, “What?”, “What is it?” or “What is it, [infant’s name]?” in an inquisitive tone, without turning away from the infants’ face. The purpose of this type of response was for to E to act as a willing interaction partner without displaying any awareness of the stimulus. This approach is similar to that of Striano and Rochat (2000), though we opted for a response without positive affect, to limit the sense that E was aware of the stimulus. E’s face remained expressionless when he was not responding to the infants, and if the infants did not look to E at any point then E remained expressionless and did not speak. After completing three cycles of activation and deactivation, E removed the stimulus from the table and placed it back behind him.

3.1.1.2 Moving Toy Task

Except for the stimuli, the procedure of the Moving Toy task was almost identical to the Interesting Sight task procedure. Stimuli for the task were: a dinosaur, a turtle, a robot dog, a robot chameleon and a humanoid robot (see Appendix 3A, Figure 3A2). Each made different noises and had different patterns of flashing lights. E activated the toy 3 times per trial, again for 5 seconds once infants had seen it, with a 5-second pause between activations. All objects moved forwards and backwards twice per activation, except the turtle which rotated in place for 3 seconds. One slight difference in the Moving Toy task compared to the

Interesting Sight task was that E only responded to the infants while the toy itself was not active, to ensure he was not speaking while the toy was producing sound.

3.1.1.3 Interesting Sound Task

Stimuli were different objects that made a noise: a “groan tube” and a “moo tube”, that each made a distinct noise when rotated, a xylophone which was struck, a sheet of paper that was crumpled noisily and a toy that clicked as it was twisted (see Appendix 3A, Figure 3A3). The table was placed in between the infants and E. E waited until the infants were looking away from E or, if the infants were unsettled, E gave them a toy as a distraction. Once the infants were distracted, the procedure was similar to the Interesting Sight and Moving Toy tasks. E activated the toy three times per trial, again with a 5-second pause in between activations. During each activation, the toy made the noise three times, with noises for each activation (e.g. the “groan tube” was flipped 3 times; the xylophone was struck 3 times). E responded to any looks to his face as above, though again he did not speak over the sound being produced. Care was taken to prevent the infants from seeing any of E’s movements. At the end of the procedure, E revealed the stimulus to the infants to make the procedure more similar to the Interesting Sight and Moving Toy procedures, in which E removed the target object at the end of the procedure.

3.1.2 Behavioural Coding

All tasks were scored using a three-level scheme to allow for analysis of the behaviours that emerged in development that were not mature forms of the target behaviour. For the joint attention tasks, “2” was given for a joint attention look. The approach taken was to be highly conservative regarding what counted as a joint attention look (score of “2”), only counting looks that we were confident were communicative. “1” was given in cases in which the infants spontaneously looked from a stimulus to E or M, but did not produce some concurrent behaviour as a comment on that stimulus (or, it was not sufficiently clear that this had occurred).

For each experimental test and the free play, infants received a single score of “0”, “1” or “2” at each session, rather than counting the number of instances of the target behaviours and basing scores on these frequencies. This was first and foremost because the quantity of looks produced within any particular task is not necessarily indicative of greater ability to initiate joint attention. Secondly, this scoring approach allowed for systematic comparisons of scores between the experimental tests and free play periods, as well as with the other tasks in the study. Given the procedural differences in terms of the length of the assessment periods and the situational set-up, comparisons using the quantity of looks would not have provided a balanced comparison.

In the present study, the infants’ mothers were always present in the room. The mothers were asked not to overtly attend to the infants, and this was facilitated by the fact that the mothers were either completing a questionnaire or reading a magazine throughout. Since the mothers were present, we did not want to ignore the infants’ looks to them as candidate behaviours; again, even in the absence of a response from the mothers, we did not want to exclude attempted initiations. Thus, in the experimental tests, if the look was to the mothers the infants could still receive a score for a joint attention look.

It is important to note that for a number of the analyses, the distinction between the 0 and 1 scores is not relevant; that is, for most of the analyses the focus is primarily on whether the infants produced a joint attention look (scored “2” vs. did not score “2”, i.e. scored “0” or “1”). Thus, we will clarify in the results section whether we are focused on the three-level scoring approach, or a binary “success” versus “failure” score. A full version of the coding scheme, represented using a flow chart, can be found in Appendix 3B, Figure 3B1. A general overview of the three-level scheme can be found in Table 3.1.

Table 3.1

Behavioural Coding Scheme for Joint Attention Looks

Score	Description
2	The infants 1) looked from the stimulus to E or M, 2) produced a distinct facial expression or vocalisation that was coordinated concurrently with the look as a comment on the stimulus, 3) produced these behaviours with a clear referent, and 4) it was clear that this sequence of behaviours was not produced in response to E or M, but was clearly initiated by the infants themselves.
1	The infants 1) looked from the stimulus to E or M, and 2) it was clear that this look was not produced in response to E or M, but was clearly initiated by the infants themselves. However, the infants did not produce a distinct facial expression or vocalisation that was coordinated concurrently with the look.
0	The infants did not look from the stimulus to E or M, looking only at the stimulus or elsewhere. If the infants did look to E or M, it was only in response to some behaviour by E or M, or the look was not clearly in response to the stimulus.

Note. The full version of the coding scheme can be found in Appendix 3B.

There are a number of important points to note regarding this scheme, particularly with regards to how it differs from previous approaches. First, schemes that focus on gaze alternation require a look from a stimulus to an agent and back to the stimulus (e.g. Bakeman & Adamson, 1984; Carpenter, et al., 1998). Here, the emphasis was on a look to the target and to the adult, without requiring that the infant look back to the stimulus. Rather, the focus was on the look from the stimulus to the adult and the concurrent behaviour accompanying this look as the key evidence of communicative intent. Additionally, the design made requiring a look back to the stimulus problematic, as the infants would likely be drawn to the stimulus once it reactivated, making it challenging to establish why the infants performed this look.

Second, there were two categories of concurrent behaviours that could co-occur with a look: facial expressions and vocalisations. The majority of previous work has focused on smiles, and for good reason; joint attention episodes often involve positive affect (Leavens et al., 2014; Messinger & Fogel, 2007). Since our focus was not solely on the sharing of positive affect, but instead on the use of a look combined with some concurrent behaviour as a referential act (Bruner, 1975; Carpenter & Liebal, 2011), we also allowed for other facial expressions, as long as it was clear that they were expressive and contingent on the stimulus (Messinger, 2002). Additionally, vocalisations were included as evidence of a communicative look. The vocalisation had to be distinct (not already occurring prior to the look), contingent on the stimulus, clearly audible, and not vegetative (a burp, yawn, etc.).

Third, the behaviours produced by the infants had to clearly be in response to an identifiable referent: the stimulus in the experimental tests, or some clear object or event in the free play period. In the experimental tests, the stimulus was either the visible object (flashing lights, moving toy) or an auditory stimulus (interesting sound). If it was not clear that the infants were producing the look in response to an identifiable stimulus, then they received a 0 for that specific look.

One of the tasks, Interesting Sound, was unique, in that there was no visible object that served as a visual target of the joint attention look. Thus, the coders needed to establish that the look was in response to the sound and not in response to some other potential stimulus in the room. One piece of evidence used was whether the look occurred promptly after the sound was produced and contingently on it. We opted not to provide an arbitrary time threshold within which the look had to occur, instead leaving this to the judgement of the coder. We found that latency was not a fool-proof indicator of whether the look was about the stimulus; infants might perform behaviours such as pausing in response to the behaviour before looking to E, or searching for the source of the noise before looking to E. These kinds of looks involved varying response latencies, and thus would have been missed if an arbitrary time threshold was applied.

Finally, the relative ordering of the behaviours was key. It was vital to be confident that neither the look to the adult nor the production of the concurrent expression or vocalisation was as a response to the adult's behaviour. In other words, the behaviours had to be clearly initiated by the infants. In the case of the experimental tests, the emotional expression or vocalisation needed to be prior to the response from E, and in the free play, neither the look nor the expression/vocalisation could be in response to something the mother had said, or to her own reaction to an event. Similarly, the expression or vocalisation needed to be a new expression or vocalisation that was about the stimulus, rather than just a behaviour that had started some time previously and had just happened to coincide with the look. For example, if the infants were repeatedly producing a vocalisation, then looked to the stimulus and E, it was not clear that the vocalisation was used as a comment on the stimulus. In these cases, the infants could not be credited with a joint attention look. Information regarding inter-observer reliability is available in Appendix 2B.

3.2 Results

The results of the joint attention tasks are reported as follows. First, the developmental emergence of infants' joint attention look production is examined by investigating the age at which infants first produced a joint attention look (collapsed across all three experimental tests and free play). Next, the methodological question of which situation was most likely to elicit joint attention looks is examined by comparing infants' joint attention look production in the experimental tests (collapsed) to the free play, and by comparing joint attention look production across each of the three experimental tests individually (and free play). After that, the question of the consistency of joint attention look production as infants aged is investigated by analysing whether infants produced joint attention looks in an increasing number of procedures (i.e. the three experimental tests and free play) with increasing age. Finally, possible earlier steps in the development of joint attention are investigated by focusing on the production of "1" scores.

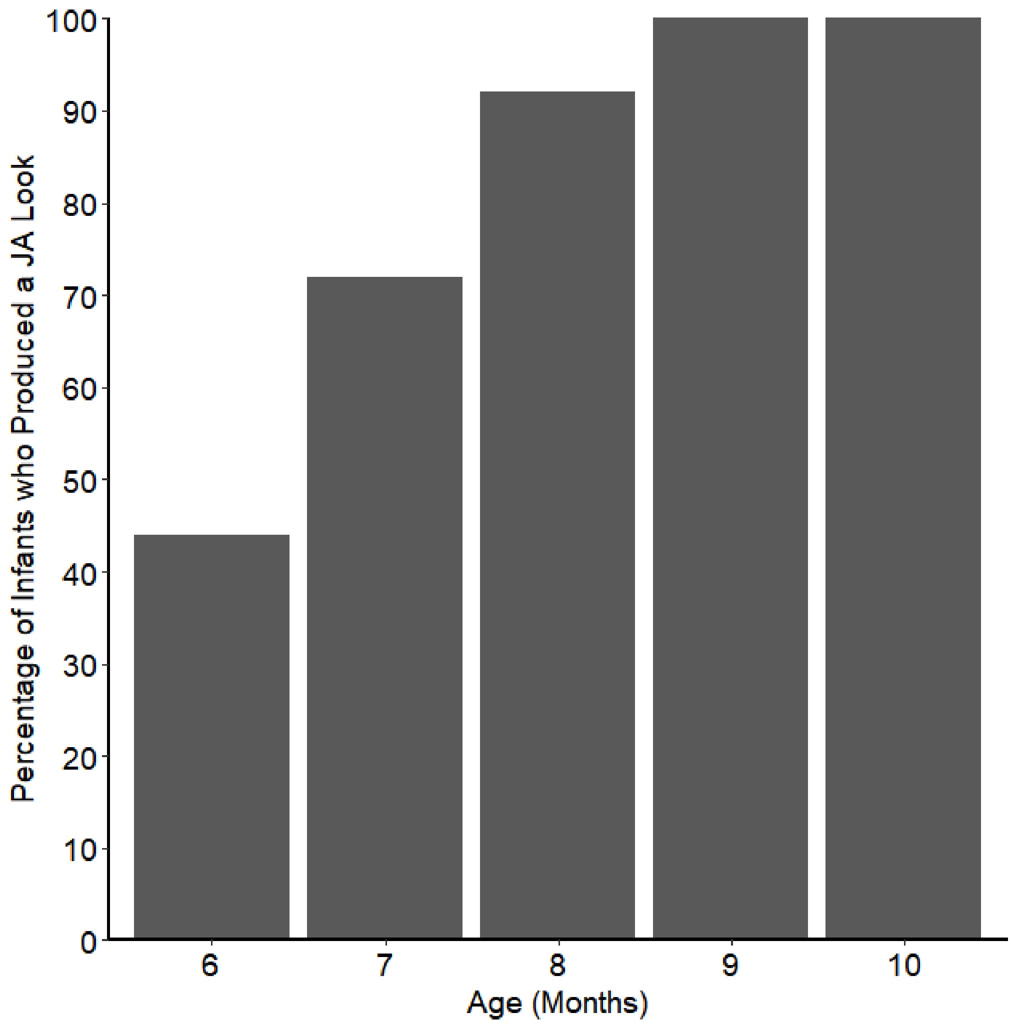
For the model used in this chapter, a generalised linear mixed-effects model (GLMM) in which participant was a random effect was compared to a GLM in which participant was entered as a factor. This allowed a statistical demonstration of which model provided a better fit. Information regarding model selection can be found in Appendix 3D. In all cases, the GLMM provided a better-fitting model. Age was entered as a categorical variable in order to conduct comparisons between scores at consecutive months. Any further fixed effects will be mentioned throughout, as will the dependent variable used in each case. In the majority of models the dependent variable was a binary outcome. Consequently, each model used a binomial error structure and logit link function unless otherwise specified. Tables of model coefficients can be found in Appendix 3C.

3.2.1 First Emergence of Joint Attention Looks

The first set of analyses focused on the emergence of joint attention looks, using scores combined across all three experimental tests and free play. Figure 3.1 displays the percentage of infants who had produced a joint attention look by each month.

Figure 3.1

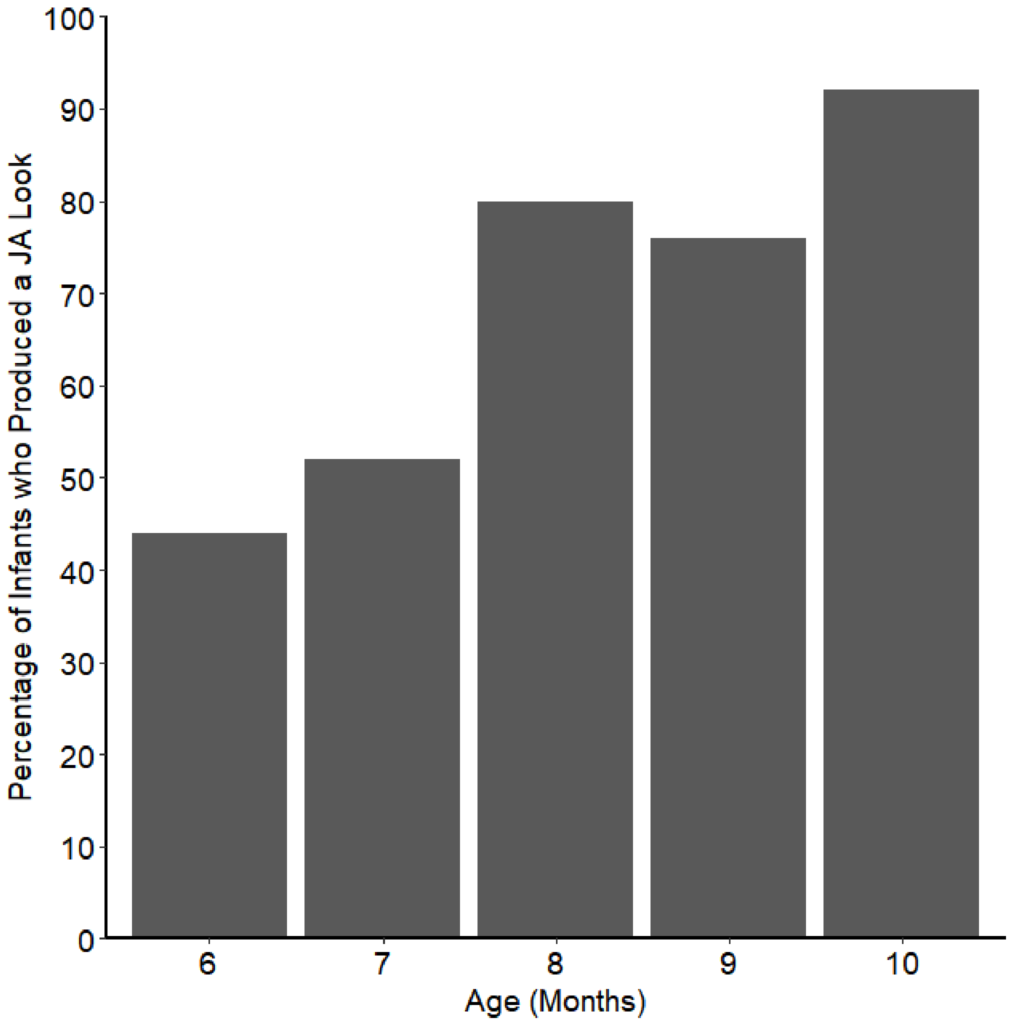
Percentage of Infants who had Produced a Joint Attention Look (Score of "2") by each Age (Cumulatively) Across all Three Tests and Free Play Combined.



At the first session, when participants were 6 months of age, 11 out of 25 infants (44%) produced at least one joint attention look, and by 7 months, 18 out of 25 (72%) had produced at least one joint attention look. By 9 months, all participants had produced at least one joint attention look. Figure 3.2 shows the percentage of infants who produced a joint attention look at each month (rather than the percentage who had passed by each month, as is shown in Figure 3.1).

Figure 3.2

Percentage of Infants who had Produced a Joint Attention Look (Score of "2") at each Age Across all Three Tests and Free Play Combined.



To address the question of whether there was a sudden increase in joint attention look production at any point, a GLMM was specified in order to examine whether a significant increase in joint attention looks occurred between any consecutive months. The dependent variable was joint attention look production (0 for no joint attention look in any task, 1 for a joint attention look (score of "2") in at least one task). The data used here were those recorded at each month, not cumulative scores. The table of model coefficients can be found in Appendix 3C, Table 3B1. A Tukey's HSD post hoc test on age revealed significant increases in infants producing joint attention looks between 6 and 10 months ($z = -2.79$, $p = 0.01$), and 7 and 10 months ($z = -2.44$, $p = 0.04$). There was no significant difference in joint attention look production between any two consecutive months.

The question of a sudden increase in joint attention look production was also assessed for the experimental tests collapsed and for the free play alone. A GLMM was specified for each grouping using the same format as the overall model. The tables of model coefficients can be found in Appendix 3C, Table 3B2 and Table 3B3. For the experimental tests, a Tukey's HSD post hoc test on age revealed a significant increase in infants producing joint attention looks only between 6 and 10 months ($z = -2.93$, $p = 0.03$). For the free play, a Tukey's HSD post hoc test on age revealed significant increases in infants producing joint attention looks between 6 and 9 months ($z = -2.83$, $p = 0.04$), 6 and 10 months ($z = -2.89$, $p = 0.03$), 7 and 9 months ($z = -2.83$, $p = 0.04$) and 7 and 10 months ($z = -2.89$, $p = 0.03$). For neither type of task was there a significant increase in joint attention look production between any two consecutive months, though there was a more sudden increase (between 7 and 9 months) in the free play than in the experimental tests.

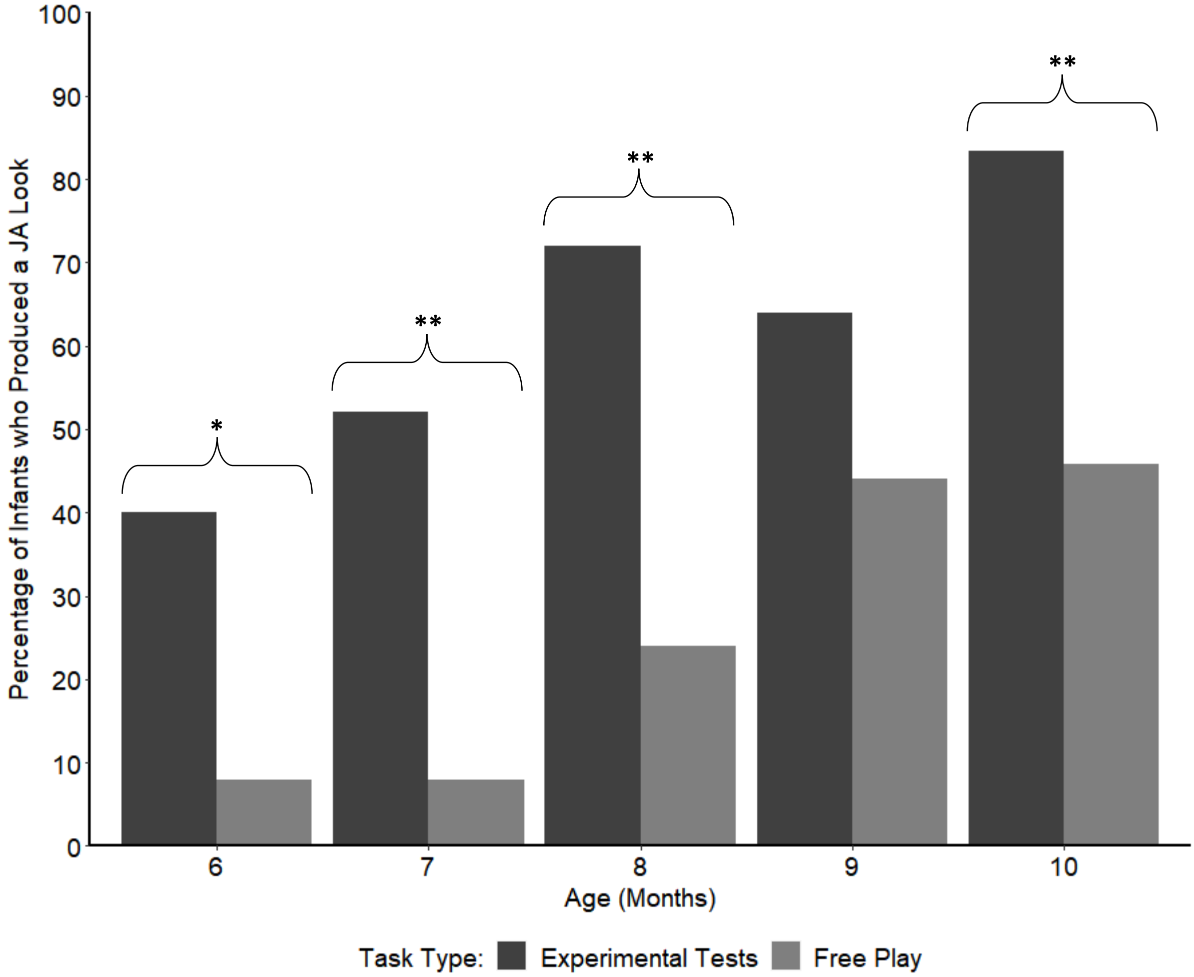
In summary, these results show that a substantial proportion of infants had produced at least one joint attention look at 6 months, with almost all infants (23 out of 25) having produced at least one of these looks by 8 months. In no instance was there was a significant increase in the number of infants producing joint attention looks between consecutive months, though there was a more rapid increase in the free play compared to the experimental tests.

3.2.2 Comparing Experimental Test Scores with Free Play Scores

The second issue to address was whether there were any differences in joint attention look production in the experimental tests compared to the free play period. Figure 3.3 shows the percentage of infants who produced a joint attention look at each month in the three experimental tests (combined) and the free play period.

Figure 3.3

Percentage of Participants who Produced a Joint Attention Look (Score of "2") at each Month, Comparing Experimental Tests (Collapsed) and Free Play



Note. *p < 0.05, **p <0.01. Experimental Test scores take the highest score received by each participant across the three experimental tests for each month. Asterisks indicate a significant difference between percentages of infants producing joint attention looks in the experimental tests (collapsed) and the free play for that month.

Analyses were conducted that examined differences between joint attention look production in the experimental tests (collapsed) and free play. A GLMM was specified, with the dependent variable being joint attention look production. The data used here were again those recorded at each month, not cumulative scores. Task type (a categorical variable:

experimental test or free play) was included as a fixed effect. The table of model coefficients can be found in Appendix 3C, Table 3C4. A Tukey's HSD post hoc test on task type revealed that the percentage of infants that produced joint attention looks in the free play was significantly lower than those in the experimental tests ($z = -5.69$, $p < 0.001$). A follow-up model was specified, with an interaction between task type and age included as a dependent variable instead of as separate variables only. The table of model coefficients can be found in Appendix 3C, Table 3C5. A Tukey's HSD post hoc test examining differences between task types at each level of age found that joint attention look production was significantly lower in the free play than in the experimental tests at 6 ($z = -2.42$, $p = 0.016$), 7 ($z = -3.01$, $p = 0.003$), 8 ($z = -3.24$, $p = 0.001$) and 10 ($z = -2.60$, $p = 0.009$) months.

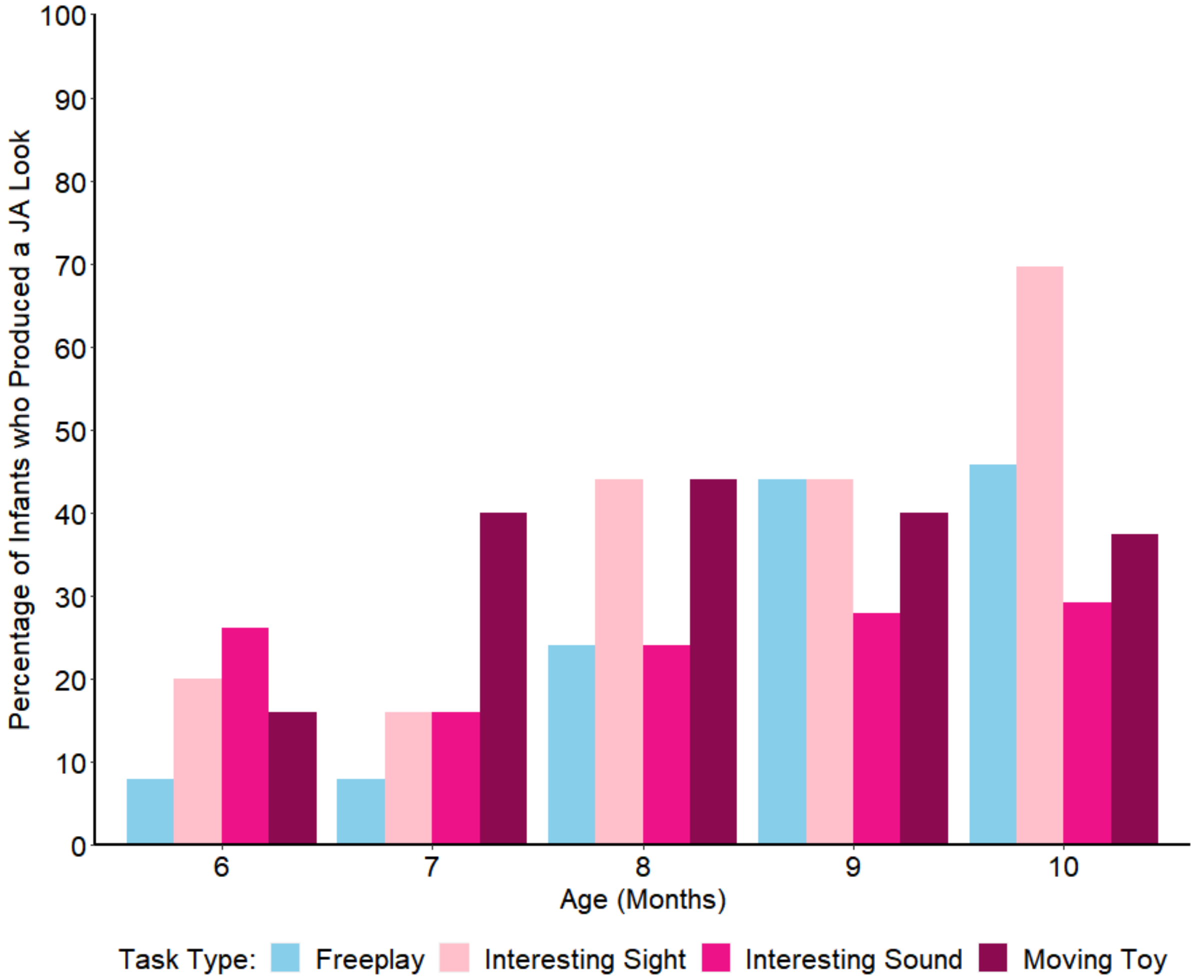
Overall, the results showed that infants produced significantly more joint attention looks in the experimental tests compared to the free play. This was true at every month except 9 months.

3.2.3 Comparing Individual Experimental Test Scores and Free Play Scores

The next issue to address was whether there were any differences in joint attention look production between each of the three experimental tests, and the free play, with the tasks separated rather than combined. This enabled assessment of how effectively each individual task type elicited joint attention looks. Figure 3.4 displays the percentage of infants who produced at least one joint attention look at each month for each of the three experimental tests and the free play.

Figure 3.4

Percentage of Infants who Produced a Joint Attention Look (Score of "2") for each Experimental Test and Free Play at each Month



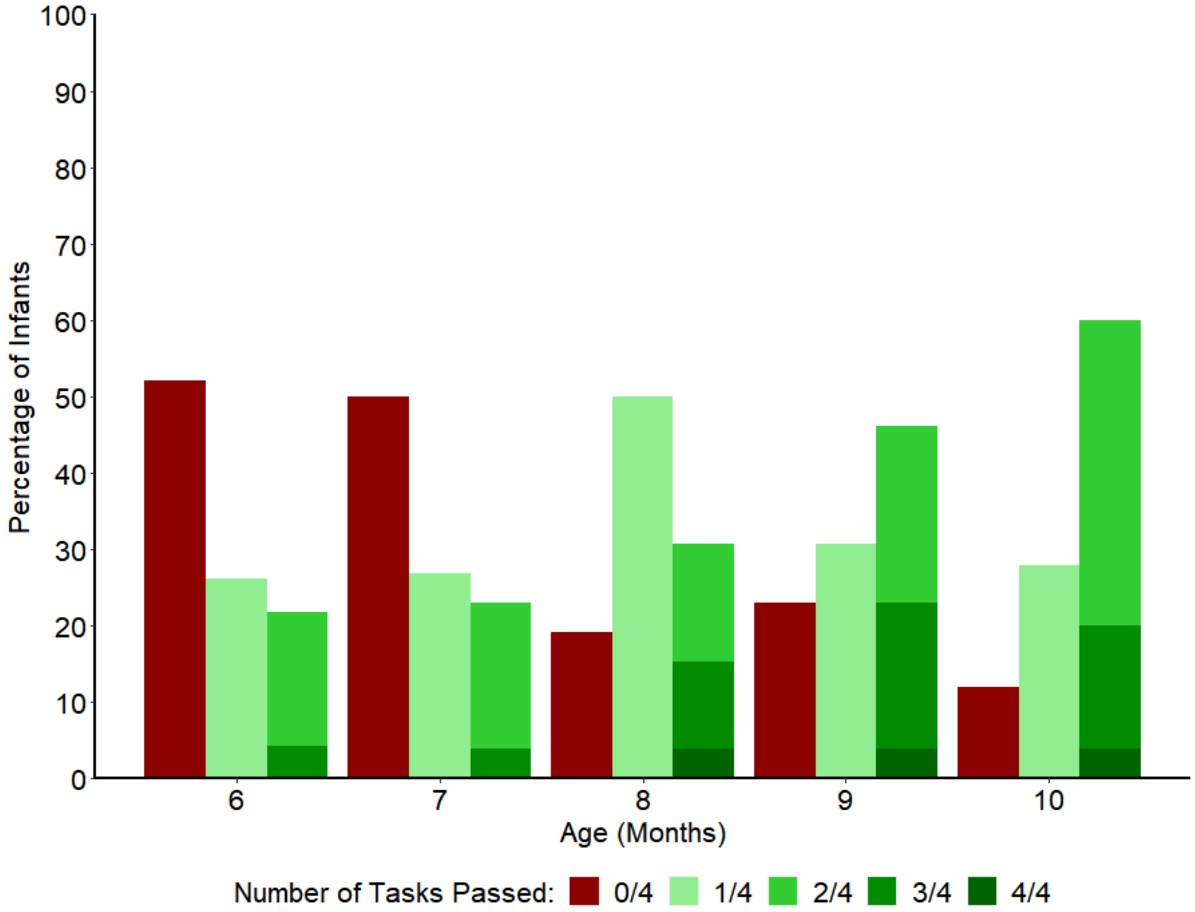
To investigate whether there were any differences in joint attention look production across each of the experimental tests and the free play, a GLMM was specified, with the dependent variable being joint attention look production. Task type (a categorical variable with each of the three experimental tests and free play as distinct categories) was included as a fixed effect. The table of model coefficients can be found in Appendix 3C, Table 3C6. A Tukey's HSD post hoc test on task type revealed no significant differences in joint attention look production across each of the three experimental tests and the free play. Because no significant difference was identified with this model, no follow-up model was specified. These results indicate that infants were no more likely to produce a joint attention look in any single experimental test or the free play.

3.2.4 Examining the Consistency of Joint Attention Look Production as Infants Aged

A further purpose of this study was to examine whether there was an increase as infants aged in how consistently infants produced joint attention looks. The number of tasks in which infants produced a joint attention look (score of “2”; on a scale from 0 to 4, including each experimental test and free play) was used as a proxy for consistency. Figure 3.5 depicts the changes in the number of tasks in which infants produced a joint attention look.

Figure 3.5

Number of Tasks in which Infants Produced a Joint Attention Look (Score of "2"), with Multiple (2 or More) Passes Stacked



To investigate whether there was an increase in how often infants produced joint attention looks in multiple tasks, a GLMM was specified. The model used a Poisson error structure and logit link function. The table of model coefficients can be found in Appendix 3C, Table 3C7. A Tukey's HSD post hoc test on age found a significant increase in how many infants produced multiple joint attention looks between 6 and 9 months (z = -2.76, p = 0.046), 6 and 10 months (z = -3.38, p = 0.006) and 7 and 10 months (z = -2.98, p = 0.025). These results show that as infants aged, they produced joint attention looks in an increasingly greater number of tasks, which can be interpreted as an increase in consistency of joint attention look production with increasing age.

3.2.5 Investigating the Origins of Joint Attention Looks

So far, the focus has been on the production of communicative joint attention looks. This section investigates the potential origins of these behaviours by examining the extent to which the communicative behaviours were preceded by non-communicative looks, which lacked the coordination of concurrent behaviours (i.e. scores of "1"). Figure 3.6 shows the highest score across all four tasks collapsed received by each participant at each session.

Figure 3.6

Percentage of Infants who Received a Score of "0", "1" or "2" as their Highest Score for Joint Attention Looks at Each Month, Collapsed across Tasks

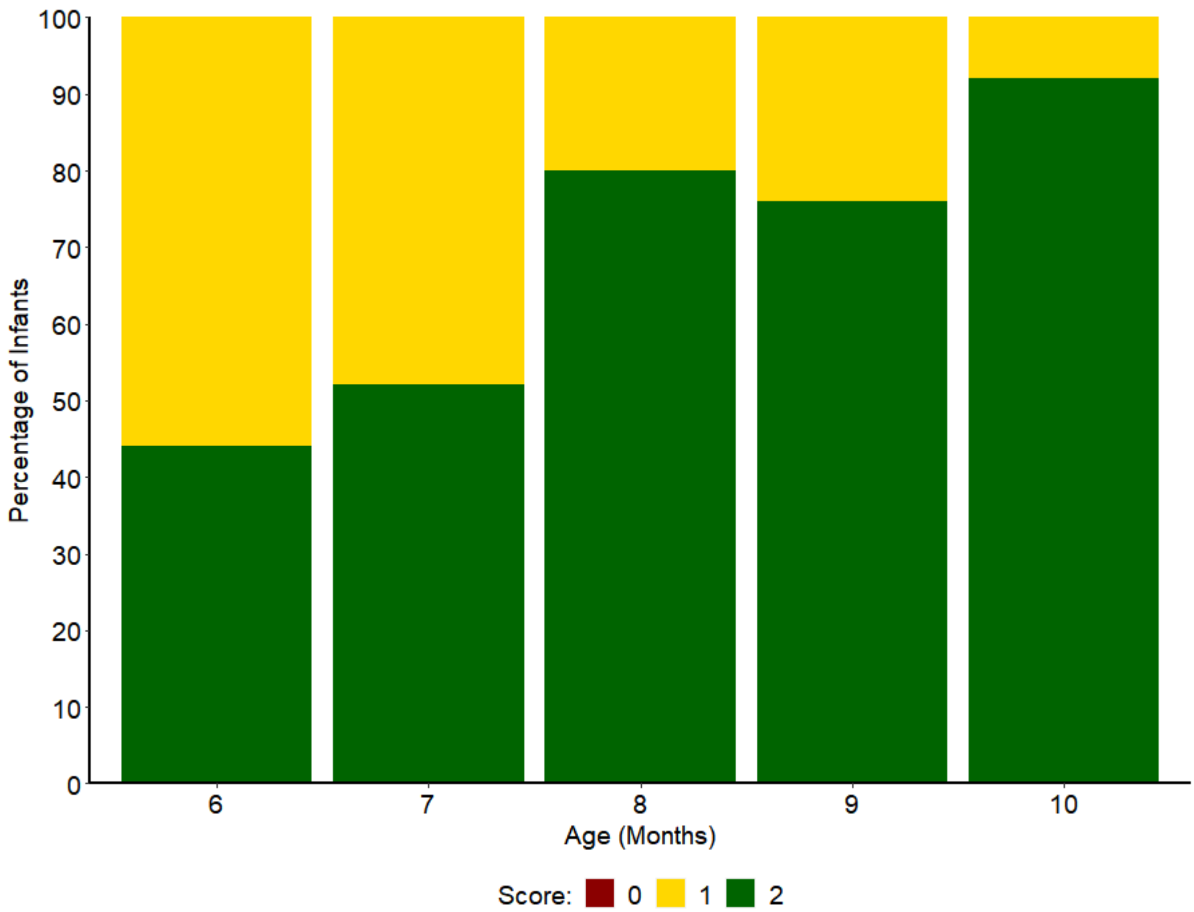
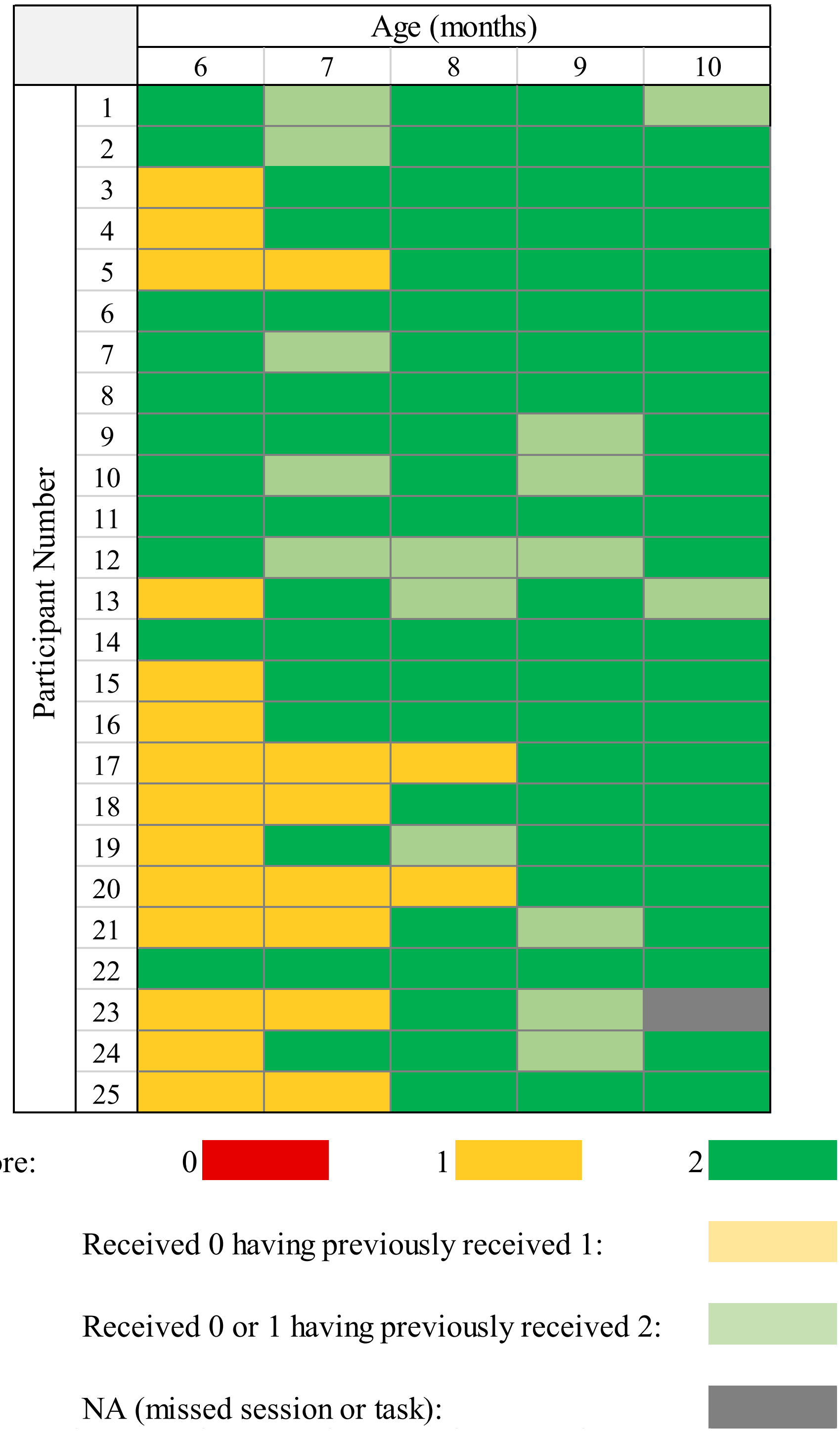


Figure 3.6 shows that all participants received a score of at least "1" at each month. Starting at 6 months, all participants looked to E or their mother in response to a stimulus.

It is also relevant to examine whether infants that produced a joint attention look continued to do so at subsequent sessions, or whether there was variability after the first observed instance. To provide more specific detail on the ordering of scores across the months of assessment, Figure 3.7 presents the developmental ordering of the scores received for each individual infant.

Figure 3.7

Individual Infants' Highest Joint Attention Look Score for Each Month, Collapsed Across Tasks



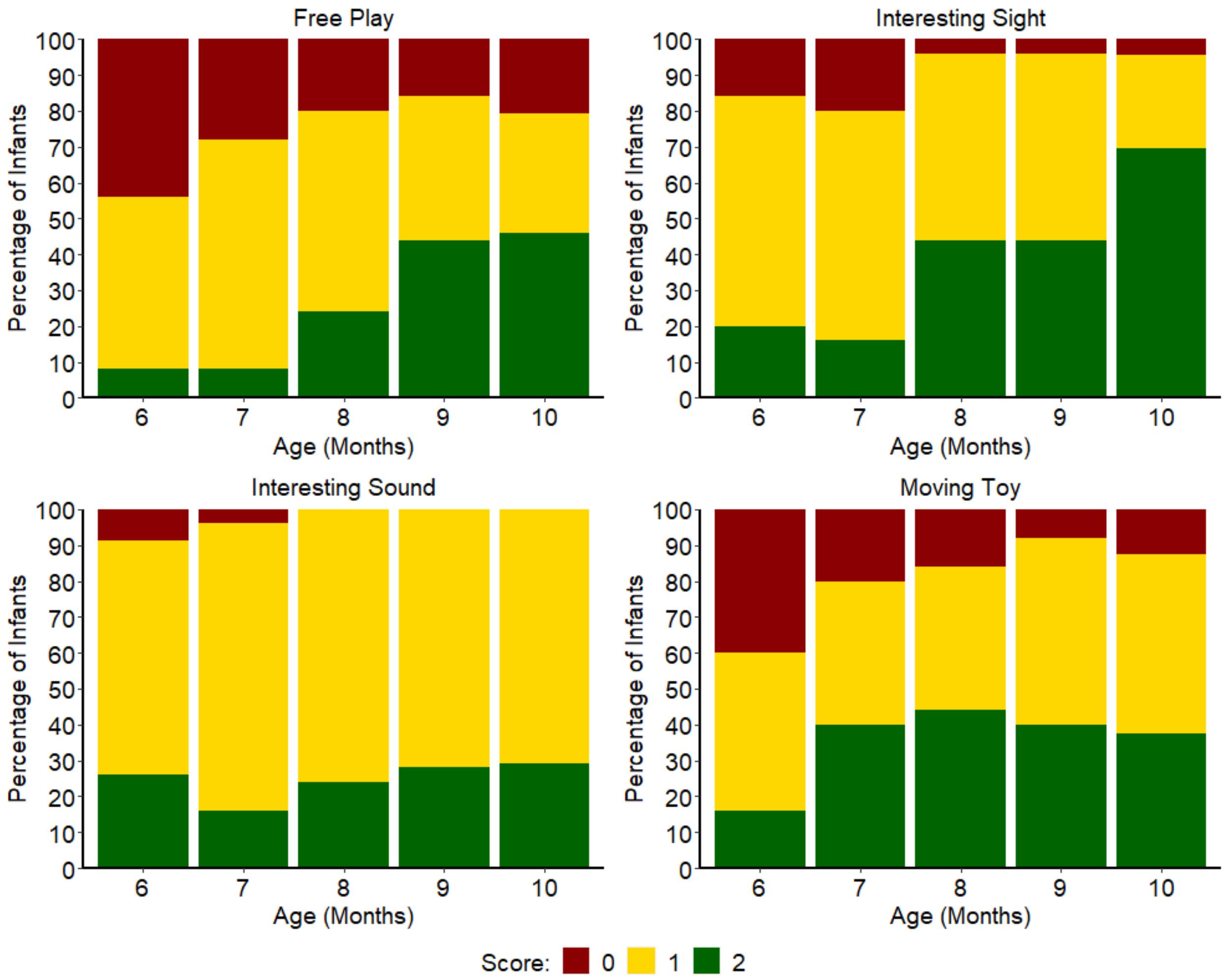
Note. For each participant at each session, the highest single score across all four tasks is used. Months at which participants' highest score was lower than a score they had received at a previous month are represented with a lighter shade.

Given the unexpectedly high numbers of participants receiving scores of “1” and “2”, it is difficult to make any strong claims about the ordering of these scores. It is not clear whether those who received a score of “2” at 6 months might have received scores of “1” at earlier months. However, in all cases in which participants did not receive a score of “2” at 6 months, they received a score of “1” at 6 months. So, while these results suggest a consistent ordering of 1’s before 2’s, future work with younger infants is needed to more clearly address this question. Figure 3.7 also reveals that participants who received a score of “2” at 6 months did not necessarily continue to receive a score of “2” at every subsequent session. While 5 of the 25 infants (25%) received a score of “2” at every session, 11 of the 25 infants (44%) had at least one case in which they received a score of 2 at one month, and then did not receive a score of “2” the following month.

Next, the scores received by infants at each month for each task type was assessed. Figure 3.8 shows the percentage of infants who received a “0”, “1” or “2” as their highest score for each separate task at each month.

Figure 3.8

Percentage of Infants who Received a Score of "0", "1" or "2" as their Highest Score for Joint Attention Looks at Each Month in Each Task



The analysis in section 3.2.3 found that there were no significant differences among tasks regarding joint attention look production (i.e. scores of "2"). However, we also wanted to examine whether there were differences among tasks when combining "1" and "2" scores into an "spontaneous social look" category. This tells us whether any particular tasks were more effective at eliciting social looks, even if those looks were not necessarily joint attention looks.

A GLMM was specified, with the dependent variable being spontaneous social look production ("0" = no social look and "1" and "2" scores collapsed into a single "spontaneous social look" score). Task type (a categorical variable with each of the three experimental tests and free play as distinct categories) was included as a fixed effect. The table of model coefficients can be found in Appendix 3C, Table 3C8. A Tukey's HSD post hoc test using task type found that spontaneous social look production was significantly higher in the Interesting Sight task compared to the Free Play ($z = -3.30$, $p = 0.005$), in the Interesting Sound task compared to the Free Play ($z = -4.35$, $p < 0.001$) and in the Interesting Sound task compared to the Moving Toy task (z = -3.67, $p = 0.001$).

Overall, these results suggest that infants were most likely to produce spontaneous social looks in the Interesting Sound task (though not any more than in the Interesting Sight task), and infants were least likely to produce spontaneous social looks in the Free Play (though not any less than in the Moving Toy task). This may have been because of the lack of an engrossing visual stimulus in the Interesting Sound task, meaning that infants were more likely to look to the interaction partner. In contrast, the Moving Toy task (with a noisy, mobile object) and the Free Play (with the opportunity to manually and orally engage with objects) may have meant that infants continued to visually attend to the stimulus rather than breaking away from it to attend to the adult.

3.3 Discussion

An influential narrative regarding the development of triadic joint attention has been that infants only begin to initiate joint attention at 9 months of age (Hubley & Trevarthen, 1979; Messinger & Fogel, 2007; Tomasello, 1999). However, the current results directly challenge this view, in that almost all infants (92%) had produced at least one joint attention look before 9 months, and over a third (44%) had produced a joint attention look by 6 months of age. Furthermore, in contrast with the notion of a "9-month revolution" (Tomasello, 1999), there was no sudden increase in infants producing joint attention looks, with no significant increase in the number of infants producing joint attention looks found in any two consecutive months. There was a more rapid increase in joint attention look production in the free play (a significant increase between 7 and 9 months) than in the experimental tests (a significant increase between 6 and 10 months), which may indicate that previous reports of a sudden increase in triadic engagements at 9 months are a consequence of examining infants' behaviour from the free play context. This work complements previous research that suggests a gradual emergence of triadic forms of engagement starting well before 9 months (de Barbaro et al., 2013, 2016; Hoehl & Striano, 2013; Rossmanith et al., 2014). However, this study is the first experimental longitudinal study focusing specifically on the capacity of infants to actively initiate joint attention to and communicate about some stimulus.

The study was also original in its use of experimental tests to elicit joint attention looks. Significantly more infants produced joint attention looks in the experimental tests than in the free play, suggesting that assessing infants' ability to produce joint attention looks from free play interactions alone may underestimate infants' actual capabilities. A plausible reason for this is that the experimental tests strip back much of the environmental complexity and have a minimally active social partner. In contrast, free play involves complex scenes with multiple objects (Koşkulu et al., 2021), as well as interaction partners (typically caregivers) who respond dynamically, and who may intervene if perceiving little or no social initiation on the part of the infant (Bruner, 1977; Vygotsky, 1978). Thus, infants' capabilities are masked, or are very difficult to clearly identify. In the experimental tests, infants encountered a single salient stimulus, and an interaction partner who allowed them an extended period (around 30 seconds) in which to produce a response, providing more optimal conditions for examining infants' capabilities. It may also be the case that infants are generally biased to look to non-caregiver interaction partners. Striano and Bertin (2005a) found that 5-, 7-, and 9-month-old infants produced more gaze shifts to a stranger's face than their mother's in free play, and Gredebäck and colleagues (2010) found that infants followed the gaze of a stranger more than they followed the gaze of their mother, with this preference emerging between 4 and 6 months of age. It is not yet clear why this is the case, but a further investigation could use this study's paradigm with caregivers to see if the same results still hold.

Additionally, in free play, infants were permitted to interact manually and orally with the objects, and may have struggled to disengage their visual attention in order to look communicatively to their caregiver (de Barbaro et al., 2016). In contrast, in the experimental tests, the stimuli were out of infants' reach. Furthermore, the stimuli regularly deactivated, providing infants with an opportunity to disengage their attention with minimal cognitive effort. A final reason that free play interactions may not regularly elicit many joint attention looks is because, as demonstrated by Yu and Smith (2013), engagements between infants and caregivers involving objects can typically proceed with minimal eye-contact, with visual attention to each other's manual activity sufficing for an interaction to continue. . In contrast, the experimental tests always involved a surprising and often exciting stimulus that was novel to both infant and adult, thus creating a situation in which a joint attention look was a more likely response.

The study also examined infants' production of spontaneous non-communicative looks (those indexed by a score of "1" in this study). All infants had produced at least one of these looks at 6 months. Previous work has shown that infants as young as 5 months can engage in these behaviours (Striano & Bertin, 2005b), but the new paradigm that has been developed may be even more effective at identifying these behaviours than doing so from free play. It is important to note that while these looks are described as non-communicative, it may be the case that this was overly conservative in some cases. For example, there were cases in which the infants' smile could not be clearly identified as anticipatory, as the adult had already reacted. However, it still may have been the case that the infant was seeking to communicate with the adult spontaneously rather than just reacting, but this was not possible to discriminate. Conversely, it could be argued that some of the joint attention looks that were identified were not truly communicative, but merely coincidental, with the infants just so happening to smile or vocalise at the right moment. Given the range of requirements that the behavioural sequences had to meet, we believe this is unlikely, but it may be beneficial to introduce further constraints on the concurrent behaviours that are coordinated with looking behaviour, such as specifying the behavioural coding of facial expressions and vocalisations in more detail.

It is also important to highlight that the approach taken was to not require that the situation be "resolved" into a joint attention situation. In other words, we understood the looks to the adult, by virtue of meeting the stringent requirements of the coding scheme, as being a joint attention look, regardless of whether the interaction outcome of joint attention was achieved. Though joint attention requires bi-directionality and mutuality (Carpenter & Liebal, 2011; Hobson, 2005; Siposova & Carpenter, 2019), it is still possible to assess attempted initiations that do not obtain as joint, such as a missed showing gesture or declarative point. For the experimental tests, this approach was taken in order to provide the infants with plenty of opportunity to produce or to persist in relevant behaviours without interruption. Additionally, if E were to attempt to react in the moment, it may have led to flawed results, either because E did not notice that a joint attention look had been produced, or because E wrongly believed that the infant had produced a joint attention look. However, it is worth noting that these beliefs about infant communication may well be a relevant topic of investigation in their own right; regardless of the "correctness" of the response, it may be fruitful to examine the kinds of situations and infant behaviours that create a sense of sharing in the moment, regardless of what subsequent behavioural analyses reveal, since the perception of communication may suffice to continue an interaction.

Finally, the study found significant individual variation in patterns of joint attention look production across the sessions. While some infants produced joint attention looks at every session, others produced these looks only at, for example, the 6- and 10- month sessions. The consistency with which infants produced joint attention looks across tasks increased significantly between 6 and 9 months, suggesting a consolidation of infants' capacity to produce joint attention looks during this period. It has previously been argued that when infants are able to initiate joint attention to some stimulus, rather than just following others' attention, they become a newly active participant in social engagements (Cohn & Tronick, 1987; Messinger & Fogel, 2007). What this study suggests is that this transition begins with infants displaying a burgeoning capacity to produce joint attention looks prior to 9 months, but that this capacity becomes increasingly consistent, enabling infants to take an increasingly active, initiating role. This view aligns with evidence that, at around 9 months, caregivers reduce the amount of social scaffolding they provide during interactions, suggesting that they are aware of infants' growing capabilities and thus provide infants with more opportunities to produce social behaviours, rather than caregivers predominantly structuring the interaction themselves (de Barbaro et al., 2013).

These findings contribute to theoretical discussions of joint attention and communication. Previous conceptual work has stressed that joint attention to be truly *joint*, involving a mutual, bidirectional relation between co-attenders, it requires active sharing through communication (Carpenter & Liebal, 2011; Eilan, forthcoming; Hobson, 2005; Siposova & Carpenter, 2019). This study emphasised the role of communication in joint attention, providing a conservative definition of joint attention looks that emphasised the need for active coordination of concurrent behaviours (facial expressions, vocalisations) with coordinated looks (e.g., Jones & Hong, 2001; Striano & Bertin, 2005a; Venezia et al., 2004). This approach to the initiation of triadic joint attention focused not only the coordination of two foci of visual attention, but the affective and motivational dimensions of triadic engagements (Carpenter & Liebal, 2011; Hobson & Hobson, 2011; Moll et al., 2021). This emphasis provides a means of assessing difficult to analyse notions such as “jointness” or “sharing” (Graham et al., 2021; Hobson, 2005) by grounding these notions in publicly observable behaviours (Leavens et al., 2014). The coordination of visual attention with concurrent behaviours such as facial expressions and vocalisations provides evidence that the infant is producing these behaviours as a comment on or reference to some target, and thus provides clearer evidence of an social act than simultaneous or coordinated looking alone (Carpenter & Liebal, 2011; Gabouer & Bortfeld, 2021; Tomasello, 1995).

This approach emphasises the continuity between dyadic and triadic engagements, by highlighting the communicative capacity at the heart of each (Hobson & Hobson, 2011; Moll et al., 2021). However, exactly how dyadic exchanges develop into triadic exchanges is still an open question. On the one hand, it may be that infants may undergo a gradual process of expansion, where dyadic communicative exchanges expand into triadic communicative exchanges, with the triadic structure gradually developing as caregivers and infants incorporate more features of the world into their communicative exchanges (Bakeman & Adamson, 1984; Moll et al., 2021; Reddy, 2010; Werner & Kaplan, 1963). On the other hand, infants may develop a capacity to integrate communicative engagement into the triadic structure of social referencing and checking, meaning that the triadic structure first develops with non-communicative looks and gaze alternation, prior to communicative joint attention looks with coordinated expressions and vocalisations. This study found that infants may look to a social partner non-communicatively prior to doing so communicatively, but the age range did not extend sufficiently early to clearly establish this developmental ordering. However, these approaches are not mutually exclusive; infants may have a range of interactive experiences through which they become capable of triadic engagements with others.

3.3.1 Directions for Future Research

The novel methods and the novel findings of the study open new directions for future research. First, a natural next step is to use these paradigms with even younger infants. This will enable us to establish when in development infants first start to produce joint attention looks, and if this does occur prior to 6 months of age for some infants. It will also allow investigation of whether joint attention looks are preceded by the ability and motivation to produce non-communicative looks. Given that all infants in this study had produced a non-communicative look (or a joint attention look) by 6 months, it is plausible that the experimental tests would elicit these responses in younger infants, but it is not clear quite how young. It may also be the case that joint attention looks are developmentally associated with dyadic communicative exchanges. Previous work has found links between dyadic and triadic skills (e.g. Striano & Rochat, 1999), but the focus on triadic skills did not emphasise the role of communication. As previous work has explored (e.g. Bakeman & Adamson, 1984) and recent work has re-emphasised (Gabouer & Bortfeld, 2021; Graham et al., 2021; Moll et al., 2021; Siposova & Carpenter, 2019), joint attention involves the coordination of a variety of skills, motivations and processes, and there are different ways of achieving joint attention (for example, an agent drawing another's attention to a novel stimulus versus an agent sharing a stimulus to which both agents are already attending). Thus, it is important to continue to examine the developmental trajectories of different kinds of abilities, from non-communicative looks to communicative looks about some object or event.

Similarly, it is important to consider the developmental trajectories of infants' capacity to both respond to and initiate joint attention (Mundy & Newell, 2007; Stephenson, et al., 2021). There is already a rich literature on attention following in infancy, with a range of studies that have made subtle procedural changes to examine a variety of contextual effects on attention following (Flom et al., 2007; Moore, 2008; Shepherd, 2010). Furthermore, investigations have been conducted with infants across the first year (e.g. Bertenthal et al., 2014; Carpenter et al., 1998; D'Entremont, 2000; De Groote et al., 2007; Farroni et al., 2004; Gredebäck et al., 2010; Morales et al., 2000), enabling a detailed developmental view of infants' attention following capacities. The literature on infants' capacity to initiate joint attention, particularly experimental work, is comparatively limited. Addressing this imbalance through further experimental examination of infants' initiation of joint attention will facilitate a deeper understanding of the relations amongst infants' developing joint attention skills.

Another relevant question to explore in future research regards the "quality" or "message" of joint attention looks (Graham et al., 2021; Hobson & Hobson, 2007). In the introduction, a case was made as to why joint attention looks are not simply to check for the presence of E or the caregiver, but to actively comment on the stimulus. However, we have deliberately avoided any stronger claims regarding what the looks might have communicated, such as being declarative ("Look at that!", or "I see/hear that too!") or interrogative ("What is that?", "Is everything OK?"). It may be possible to identify behavioural differences (such as facial configuration) that index different kinds of joint attention looks that convey different kinds of "messages." Yet, it is important to be cautious with these attempts at glossing the looks; these looks are not univocal signals that are straightforwardly interpretable as propositions. Infants become increasingly skilled at communicating in different ways as they become capable of coordinating looks, vocalisations and gestures (Esteve-Gibert & Prieto, 2014; Liszkowski, 2014; Salo et al., 2018). Thus, the question remains as to whether infants who are just starting to produce joint attention looks are able to convey specific communicative intentions (e.g. declarative or interrogative), or initially communicate simpler "messages" such as positive or negative affect, with more complex communicative intentions only being conveyed later in development.

A further important feature of this study was the use of varied stimuli across different tasks, including sight, sound and motion. An issue for future exploration is how infants come to be capable of sharing different kinds of stimuli. Recent theoretical accounts have drawn attention to the multi-modal nature of joint attention (Battich et al., 2020; Botero, 2016; Gabouer & Bortfeld, 2021; Siposova & Carpenter, 2019), but there remains little research into infant responses to non-visual stimuli such as sounds, smells, or tactile sensations. Infants' lives are replete with shared experiences of varied stimuli, with different stimuli and modalities often experienced simultaneously. Thus, our understanding of the development of joint attention would benefit from a deeper understanding of the role played by sounds, smells and tactile sensations. Furthermore, there is variety in how different stimuli are experienced. Consider a joint attention situation involving a sound being emitted from a specific location, versus a non-localised sound, such as the sound of falling rain or of a crowd. There is little work that considers how infants (or indeed older children or adults) might share these different kinds of sensory experiences. This may be because of the practical challenges of working with different stimuli, both in terms of the implementation of experimental protocols and the development of behavioural coding schemes. For example, our experience of coding responses to sounds was that it was more complex than coding visual stimuli due to the lack of a clear "anchoring point" in space as the target of the look. Meeting this challenge will thus require creative ways of approaching experimental design and behavioural coding in order to assess infants' responses to varied stimuli, as well as investigation of infants' responses to different stimuli in their daily lives.

Finally, it is important to note that the sample used is from a "WEIRD" population (Henrich et al., 2010; Nielsen et al., 2017); all infants were living in a rich, Western, democratic nation, with educated parents. The observed developmental trajectory of joint attention looks may be a particular feature of this cultural context. Further work could attempt to use this paradigm in different cultural contexts to examine potential differences in the developmental emergence of joint attention looks. It would also be important to consider the relevance of the target stimuli across cultures. Flashing lights and remote-controlled toys are likely to be highly unfamiliar in some contexts, and thus responses to these stimuli may not be truly reflective of those infants' capabilities. It has also been suggested that non-WEIRD cultures are less dependent on the visual modality, with a greater emphasis on physical contact (Akhtar & Gernsbacher, 2008; Botero, 2016; Little et al., 2016). For example, research by Little and colleagues (2016) found that Ni-Van caregivers (from the Pacific island of Vanuatu) more frequently used physical contact in their triadic engagements, compared to American caregivers who used the visual modality more often. However, studies have also found that, across different cultures, infants at around 1 year of age engage in social behaviours such as communicative pointing and gaze following (Callaghan et al., 2011; Liszkowski et al., 2012). Thus, a key challenge for future work is to identify variations and commonalities in early communicative and social behaviours across cultural contexts.

3.4 Conclusion

To summarise, this study contributes to a growing literature emphasising infants' gradually emerging capacity to actively initiate joint attention, providing evidence that some infants are capable of producing communicative joint attention looks to initiate joint attention from at least 6 months of age. This looks not only involve shifting of gaze, but the coordination of looks with other concurrent behaviours that suggest that these acts are communicative "comments" on some feature of the world. This study has also provided novel methodological tools for examining infants' earliest communicative behaviours, joint attention looks. These methods have been demonstrated to be more effective at eliciting joint attention looks than free play, allowing newly detailed assessments of infants' capacity to produce joint attention looks. In addition to communicative joint attention looks, infants production of non-communicative looks were also examined, with this preliminary evidence suggesting infants may be capable of such looks from earlier than 6 months, before they produce communicative joint attention looks. Finally, it was found that as infants aged, they produced joint attention looks across more tasks. This was interpreted as evidence that infants become capable of producing joint attention looks more consistently as they age.

CHAPTER 4

THE DEVELOPMENTAL ORIGINS OF COMMUNICATIVE GESTURES: FROM INCIPIENT TO CONVENTIONAL FORMS

Understanding the origins of infants' intentional communication requires understanding the emergence of communicative gestures, as they are among infants' first communicative behaviours (Bates et al., 1979; Carpenter et al., 1998). Gestures are one of the earliest means that infants employ to establish joint attention and communicate with others (Bates et al., 1979; Carpenter et al., 1998; Werner & Kaplan, 1963), and previous work has repeatedly highlighted the ways in which communicative gestures are developmentally associated with later social abilities, especially language (Bates et al., 1979; Carpenter et al., 1998; Choi et al., 2021; Salo et al., 2018; Wu & Gros-Louis, 2014). Much previous work has focused on pointing as the key early gestural means of establishing joint attention, likely because it provides a particularly clear case of referential behaviour which is employed frequently by infants (Butterworth, 2003; Stephens & Matthews, 2014), is easy to elicit (Liszkowski et al., 2004; Liszkowski & Tomasello, 2011), and is found across a wide range of cultures (Liszkowski et al., 2012; Salomo & Liszkowski, 2013). However, the focus on pointing has meant that other key early gestures have been neglected (Cameron-Faulkner et al., 2015).

However, if we want to understand the very beginnings of gestural communication, we need to investigate other key, earlier-emerging gestures such as showing, giving and requests (Bates et al., 1979; Boundy et al., 2016, 2019; Cameron-Faulkner et al., 2015; Carpenter et al., 1998; Ramenzoni & Liszkowski, 2016). Showing involves holding up objects so that others can see them (Cameron-Faulkner et al., 2015), giving involves placing and releasing an object into another's hand (Xu et al., 2016), and requesting involves behaviours like communicative reaching, produced to obtain an object or to get assistance

(Ramenzoni & Liszkowski, 2016). These gestures typically first emerge at around 9 to 10 months, typically before pointing (Bates et al., 1979; Cameron-Faulkner et al., 2015; Carpenter et al., 1998), and, like pointing, there are developmental associations with later language, particularly for showing and giving gestures (Beuker et al., 2013; Choi et al., 2021). It is therefore striking that there is so little research on the development of these earlier-emerging communicative gestures. There is a need for clear strategies for identifying the earliest communicative gestures infants produce, as well as a need for detailed assessment of their developmental emergence (Boundy et al., 2016; Boundy et al., 2019; Cameron-Faulkner et al., 2015).

The research that has investigated these gestures has primarily investigated when the conventional, mature forms of these behaviours emerge in development. In understanding the developmental pathway to conventional gestures, it is important to establish the key features that mark a gesture as conventional. Broadly speaking, conventions are reliable patterns in social interaction that facilitate communication and coordination (Lewis, 1969). Conventional gestures are recognisable by caregivers, with a consistent behavioural form that is used regularly and predictably in communicative contexts (Bates et al., 1979). Importantly, they are also recognisable by members of the community beyond the caregiver-infant dyad (Bates et al., 1979).

However, there is an important yet relatively underexplored issue in the study of infants' early communicative gestures: how ought we to understand the processes and changes that lead to the emergence of conventional gestures? This question has previously been asked of the origins of pointing gestures. A number of studies have sought to address this question (Brune & Woodward, 2007; Butterworth, 2003; Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018; Liszkowski & Rüther, 2021; Masataka, 2003; Matthews et al., 2012; O'Madagain et al., 2019). Vygotsky (1978) suggested that pointing might emerge as a result of failed reaches for out-of-range objects, though it has been suggested that this can only explain imperative points (Matthews et al., 2012). In recent research, it has been argued that declarative pointing emerges out of touch (Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018; Masataka, 2003; O'Madagain et al., 2019). However, debates persist regarding the extent to which pointing emergence is a result of processes of socialisation by caregivers (Bates et al., 1975; Carpendale & Carpendale, 2010; Cochet & Vauclair, 2010) or a result of other sociocognitive developments, such as the ability to understand others' intentions and attention, rather than direct socialisation of pointing itself (Butterworth, 2003; Matthews et al., 2012). Regardless of the different positions taken by researchers, it is apparent that the developmental origin of pointing is an active area of research that has inspired much interest and debate.

For the emergence of showing gestures, the literature is sparse. Although several studies have documented when showing emerges in its conventional form (Bates et al., 1979; Boundy et al., 2016; Cameron-Faulkner et al., 2015; Carpenter et al., 1998), none has explored where showing comes from developmentally. In contrast, some studies have explored the development of giving gestures. Carpendale and colleagues (2021) reported diary entries in which caregivers described the giving behaviours of their children from 7.5 months to 2 years, 6 months of age. They reported some descriptions of behaviours that preceded conventional giving gestures. For example, caregivers reported infants putting food or other objects into the caregiver's mouth as an early form of giving. Other studies have highlighted the role of give-and-take interactions in giving development, using case studies (Bruner, 1977, 1983), observations (de Barbaro et al., 2013), and experiments (Hay & Murray, 1982; Xu et al., 2016). For example, Xu and colleagues (Xu et al., 2016) demonstrated the influence of social experience on the development of giving in response to a request. They compared two 1- to 2-week interventions in which 7.5-month-old infants either engaged in give-and-take interactions with their caregiver or had experience putting a toy in a bucket. Only the interactive intervention led to a significant increase in giving, and infants in the interactive condition gave objects significantly more than those in the bucket condition.

Focusing on requests, Ramenzoni and Liszkowski (2016) found that 8-month-old infants were more likely to reach for objects that they knew were out of their reach when in the presence of another person (a caregiver or less familiar adult). The authors suggest that these acts are not communicative per se, but are produced with the aim of another detecting one's goal. This suggests that infants have a burgeoning awareness of how their actions can be used socially to achieve instrumental goals, prior to the use of communicative request gestures.

The current study explores the very beginnings of infants' early showing, giving, requesting and pointing gestures, focusing on where they come from developmentally, and the transition from pre-conventional to conventional forms. That is, conventional gestures do not emerge without developmental precedent, so we examined related behaviours – partial, attempted, unclear, or idiosyncratic forms of the gesture – that emerged in infants before conventional showing and giving. We label these forms *incipient gestures*. Our aim was not just to document these earlier incipient forms, but also to consider how they – and caregivers' interpretations of them – relate to the emergence of conventional forms. We also consider whether infants intend these incipient behaviours to be communicative.

As outlined in Chapter 2, a three-level coding scheme was adopted, with scores of "0", "1" and "2" assigned for each behaviour we analyse. In creating the three-level coding scheme for communicative gestures, several important strategic choices were made. With the scores of "2", again we wanted to be stringent in our approach, ensuring that we could be highly confident when we claimed to identify an instance of a communicative gesture. Part of this strategy involved requiring that for each gesture type, infants visually attended both to the target object and to the adult. Whilst in some cases this may be overly conservative (Liszkowski, 2010), the insistence on looks to both object and adult provided an important indicator that behaviour was communicative. Finally, the definitions did not simply highlight the behavioural *form* but also the *function* of these acts. For example, we treat a "showing gesture" not solely in terms of how the infant moves and holds their arm, but in terms of their achievement of bringing an object into the visual attention of an interaction partner.

We took a broader approach to the scores of "1". Our aim was to identify behaviours that were plausibly part of the developmental trajectory towards the emergence of the conventional behavioural form. Thus, we allow a greater range of potential behaviours to fit into the "1" category. We conceptualised these behaviours as potentially *partial* or *attempted* instances of a communicative gesture, which had features of the mature gesture but lacked important components. Once we identified them, we wanted to know how regularly they occurred as precursors to the conventional forms.

Maternal reports, taken from semi-structured interviews that included questions about the development of gestures, were also examined. Understanding what caregivers interpret as gestures, or possible gestures, is relevant for two main reasons. First, it provides insight into the kinds of behaviours that produce responses from caregivers, and thus which serve as an input into the cycles of interactive engagement that have been highlighted as a key facet of social development (Bruner, 1983; Vygotsky, 1978). Second, caregivers have a large number of opportunities to engage with and observe their infant, in a range of social situations (Adolph et al., 2008). Thus, they are uniquely positioned to observe subtle and gradual developmental changes and infrequently-occurring behaviours (Carpendale & Carpendale, 2010).

4.1 Method

Infants participated in a range of tasks designed to elicit communicative gestures. The procedures and behavioural coding strategies for each gesture type are outlined in turn in this section. Information on reliability can be found in Appendix 2B, Table 2B1. It was expected that there would be infants who received no score of “2”. In order to confirm that the infants were eventually capable of producing each gesture type, when the infants were 12 months of age we asked mothers to respond to questions asking whether their infant produced each type of gesture. These questions were taken from the UK-CDI (Alcock et al., 2020). Respondents to the CDI can select “Not yet”, “Sometimes” or “Often” as their response. If the mother responded “Sometimes” or “Often”, it was treated as a score of “2” in the analysis. If infants received a “0” at every session, they were excluded, as it was not possible to determine whether they would subsequently produce a “1” or a “2” between 10 and 12 months.

Mothers also took part in semi-structured interviews at each monthly session, with some of the questions covering gestural development. In order to provide insights into maternal understanding of gestural development, relevant comments regarding each gesture type are also discussed.

4.1.2 Giving Gestures

4.1.2.1 Procedure

The table was placed between E and the infants. The infants were encouraged to take a toy, which E ensured was one that the infant was capable of gripping. If the toy presented was too large, the infant struggled to grasp it, or the infant was not interested in it, E presented another toy from the set until an appropriate toy was found. E let them play with the toy for around 5 seconds, before extending his arm forward with an open, upward-facing palm and saying "Hi, [infant's name], can I have the toy, please?" E waited for 5 seconds for a response. If the infants did not respond, or did not place the toy in E's hand, E repeated the action twice more, saying, "Can you give me the toy?" or "Can I have the toy, please?" If the infant did place and release the object in E's hand, E thanked the infant and the trial ended.

Because it proved challenging to confidently and conservatively code giving gestures from the free play period, we opted not to code giving gestures from the free play period. A gesture like a communicative give is particularly dependent on the response of the interaction partner (Cameron-Faulkner et al., 2015). In a dynamic, open-ended free play period, it is difficult to be confident whether an infant has genuinely produced a giving gesture, rather than the mother pre-emptively taking the object. Thus, to be conservative in our assessment of conventional giving gestures, we coded gives only from the give elicitation task.

CDI Question. For the 12-month follow up, the UK-CDI question that examines giving gestures is worded as follows: "Reaches out and gives you a toy or some object that she or he is holding."

4.1.2.2 Coding

An overview of the three-level coding scheme for giving is presented in Table 4.1.

Table 4.1

Behavioural Coding Scheme for Communicative Giving Gestures

Score	Description
2	The infant placed the object into E's hand and released it, such that the object remains in E's hand. The infant visually attended to both the object and E's face and hand during this process.
1	The infant placed the object against E's hand, but did not release it, or released it in an uncontrolled manner such that it did not remain in E's hand. Or, the infant placed and released the toy into E's hand, but did not look to E's face at any point.
0	The infant ignores E's hand, accidentally bashes the object against E's hand, or accidentally releases the object into E's hand.

Note. The full version of the coding scheme can be found in Appendix 4A.

For scores of "2", we wanted to ensure that the infant placing the object into E's hand was an intentional, controlled act. Since the infant might accidentally release the object into E's hand (e.g. losing interest in the toy and happening to drop it into E's hand), to obtain this score, we required that the infant look at both E's outstretched hand and E's face (making eye-contact) during the process of giving the object. Scores of "1" did not have to be communicative, but it did have to be clear that the act was intentional. For this reason, the infant had to look at E's hand during the process of putting the object in E's hand. For example, the infant did not receive a score of "1" if they were looking away from E and happened to brush the object against E's hand.

4.1.3 Showing Gestures

4.1.3.1 Procedure

Two elicitation tasks and the free play period were used to assess the emergence of showing gestures. The purpose was to create two kinds of situation; one in which infants might share a previously-shared object with E (Liebal et al., 2010), and one in which they might share an object that had not previously been shared (Liszkowski et al., 2007). The two elicitation tasks were randomly assigned to either the start or the end of the Task period. In both conditions, the infant sat at one end of the mat. He/she either sat independently in front of his/her mother, or was propped up against his/her mother. The infant was presented with a toy, and E briefly showed interest in the toy and spoke to the infant. E then left the room, closing the door behind him.

Same Toy Task. In the Same Toy condition, the mother was asked beforehand to continue to play with the infant and the toy while E was absent, but to be silent once E returned. E waited for 10 seconds, before re-entering the room. Upon re-entry, for the response phase, E looked only to the infant's face and uttered three phrases, repeating each once before going on to the next one: "Hello!" or "Hello, [infant's name]!"; "How are you doing?" or "How are you?"; "Are you having fun?" or "Are you having fun, [infant's name]?" E paused for a few seconds between each utterance. The aim was to avoid explicit reference to the toy, neither looking at the toy nor verbally referring to it. Once E had uttered all the phrases, he waited a further few seconds, before the trial finished.

New Toy Task. In the swap condition, the mother was given a new toy (without the infant witnessing). The mother was asked beforehand to wait until E had exited, and then swap the initial toy for the new toy. Again, she was asked to remain silent once E returned. E waited until the swap was successful, typically approximately 10 seconds, before re-entering the room. Upon re-entry, E looked back and forth between the infant's face and the new toy. He uttered three phrases, repeating each once: "Wow!"; "That's cool!"; and then "Can you show me the toy?" or "Can you show me the toy, [infant's name]?" E paused for a few seconds between each utterance. The aim was to refer explicitly to the new toy, and to give infants a chance to show it spontaneously but also to provide an explicit request to gradually escalate the requests for the infant to show E the toy. Once E had uttered all the phrases, he waited a further few seconds, before the trial finished.

The two tasks were deliberately distinguished in three areas: keeping the same toy or swapping the toy; alternating gaze between the toy and the infants' eyes; and using phrases that referred directly to the toy or not. Thus, there were two types of situation; one (Same Toy) which involved generic interest in the infant as he/she held a previously shared toy, and another (New Toy) which involved interest in a new, non-shared toy. This provided two distinct kinds of situations for eliciting showing gestures.

CDI Question. For the 12-month follow up, the UK-CDI question that examines showing behaviour is worded as follows: "Extends an arm to show you something she or he is holding."

4.1.3.2 Behavioural Coding

The same coding strategy was used in all three tasks. An overview of the scheme is presented in Table 4.2.

Table 4.2

Behavioural Coding Scheme for Showing Gestures

Score	Description
2	The infant produced a conventional, communicative showing gesture, involving three key components: *raising* the object into the view of the adult, *stabilising* the object at least briefly so it remained within the view of the adult, and *visually attending* to both the object and the adults' face.
1	The infant produced a sequence of behaviours with either the *raising* and *visually attending* but not the *stabilising* components above, or else the *raising* and *stabilising* but not the *visually attending* components.
0	The infant made no attempt to produce a showing gesture, or produced no clearly relevant action.

Note. The full version of the coding scheme can be found in Appendix 4A.

As previously stated, the scores of "2" were conservative, requiring several components to be present to ensure confidence that infants were producing clear, conventional showing gestures. We specified *raising* as being above shoulder height. Whilst it is in principle possible to show lower than shoulder height, we could be more confident that the infant was genuinely trying to bring the object into view if this was the case. For *stabilising*, the object did not have to be perfectly still, but did have to remain in view of E/M; shaking the toy slightly having raised it was fine, but flailing the toy around was not sufficient. For stabilising, the object did not have to be perfectly still for an extended period of time, but did have to remain in view of the adult for at least one second. Shaking the toy slightly having raised it was fine, but flailing the toy around was not sufficient.

The scores of “1” were assigned to intentional but not necessarily communicative behaviours, whereby infants produced some but not all of the behavioural components of a show. Of the components, we required raising to be present for any “1”; otherwise it was not clear that the object was being brought into E/M’s visual attention. However, in line with our strategy of viewing “1” scores as attempts or approximations of the conventional behavioural form, we set a less strict threshold for raising, making it above chest height rather than shoulder height. There were two possible combinations of the components for the score of “1”. The first was *raising* and *visual attention* (with no *stabilising*), which captured cases in which infants looked to both the object and E/M, raised the object into his/her view, but did not keep it sufficiently stable (for example, by flailing it up and down). The second was that of *raising* and *stabilising* with no *visual attention* to both the object and E/M’s face. As with scores of “2”, for the *stabilising* component, the object had to be moved into E/M’s view and kept there for at least 1 second.

4.1.4 Request Gestures

4.1.4.1 Procedure

Request gestures were coded from three tasks. As with giving, we did not code proximal request gestures from the free play period, choosing to focus on those situations which had been specifically constructed (or were specifically suited) to elicit these gestures. Two types of requests were coded for: *proximal* and *distal.* A proximal request is the act of presenting an object to another (e.g. by sliding it towards them) in order to request assistance with it, and a distal request is a gesture (such as a communicative reach) is used to request an object that is out of reach.

Transparent Box Task. E sat on the other side of a table from the infant. E got the infant's interest in a toy, moving it in front of them until they attempted to grasp it. Once the infant had responded, E placed that toy inside a transparent plastic box (Appendix 2A, Figure 2A6), and sealed the lid. The infant was then allowed to interact with the box. The infant was given up to 40 seconds to interact with the box and produce any social behaviours. E was faced towards to the infant with a neutral expression, and said "What is it?" if the infant made eye-contact. If the box moved out of the infant's range, dropped off the table or was thrown off the table by the infant, E placed it back in front of the infant without speaking. If the infant became visibly upset, the trial was ended. If the infant produced a clear, communicative request, E removed the toy from the box, gave it to the infant and the trial was ended. If, by the end of the 40 seconds, the infant had not produced a clear, communicative request, E took the box, removed the lid and showed the infant the toy, before providing a different toy for the infant to play with.

Out of Reach Object Task. E sat on the other side of a table from the infant. E got the infant's attention to the toy, moving it in front of them until they attempted to grasp it. Once the infant had responded, E placed the toy at the far end of the table, out of the reach of the infant. E then waited for a response period of 20 seconds. Less time was given compared to the Transparent Box task as the infants were not provided with anything with which they could physically interact, which typically (as identified through piloting) reduced the time they were willing to participate in the task. If the infant became visibly upset before 20 seconds had elapsed, the trial ended. At the end of the trial, E removed the toy from the table, before providing a different toy for the infant to play with.

Cloth Task. The cloth task, a task focusing on assessing means-ends understanding (Willatts, 1999), was also used to assess requesting gestures. The table was placed between E and the child. E placing a cloth (folded to be 21 by 69cm) lengthwise between them along the surface of the table, such that one end of the cloth was in range of the infant's grasp. Whilst placing the cloth, E established the infant's interest in a toy in order to distract the infant from the placement of the cloth. The initial position of the table was such that the near end of the cloth was initially out of the child's reach. If the infant was uninterested in the toy, a different toy was chosen until one was found that the child found interesting. Once the cloth was in place, and the child had showed interest in the toy, E placed the toy at the far end of the cloth from infants' perspective and slid the table and cloth forwards until the near edge of the cloth was within the child's reach. The infant was then given 20 seconds to obtain the toy using the cloth. If the infant obtained the toy, E took it from them, and if they did not obtain the toy, E removed it from the cloth and ended the procedure. E ended the task if the child was visibly upset. If the infant pulled on the cloth too hard and the target object fell to the floor, they were given another chance (within the allocated time).

CDI Question. For the 12-month follow up, the UK-CDI question that examines requesting behaviour is worded as follows: "Requests something by extending arm and opening and closing hand." Whilst this did not describe the exact same gestures that were assessed in the behavioural aspect of the study, it provided some indication of whether the infant produced requesting gestures.

4.1.4.2 Behavioural Coding

An overview of the three-level coding strategy for proximal requests is presented in Table 4.3.

Table 4.3

Behavioural Coding Scheme for the Transparent Box Task

Score	Description
2	The infant intentionally, communicatively presented the box to E as a request for assistance with it. This required pushing the box towards E such that it ends up in front of E (i.e., not just a slight push), and then releasing both hands from the box. The infant must visually attend to both the object and E during the process.
1	The infant pushed the box towards E, looking at both the object and E, but did not release the box with both hands. Or, the infant pushed the box to E and releases it, but does not look to E during this process.
0	The infant explored the box without pushing it towards E, or ignores the box.

Note. The full version of the coding scheme can be found in Appendix 4A.

The requirement to release the object for a score of “2” was introduced to be conservative regarding infants’ intention. If the box was slid forward by the infant and not released, it was not fully clear whether this act was a request for assistance (rather than doing so as part of their exploration, or perhaps showing the box). For scores of “1”, one of the components had to be missing; either the release of the box or visual attention to the box and E.

An overview of the three-level coding strategy for distal requests is presented in Table 4.4. This scheme was used for both the Out of Reach Object Task and the Cloth Task.

Table 4.4

Behavioural Coding Scheme for Distal Request Gestures

Score	Description
2	The infant produced a request gesture to request the target object. This was either a communicative reach or a point. The infant visually attends to both the target object and the adult during the process.
1	The infant produced a possible or attempted request gesture, which lacks the clear behavioural form (such as the hand not being clearly held towards the target object, or the fingers being curled into a fist). Or, the infant produced a request gesture but did not visually attend to the object and E during this process.
0	The infant made no attempt at producing a distal request gesture, or produced no clearly relevant action.

Note. The full version of the coding scheme can be found in Appendix 4A.

On this scheme, pointing gestures are recognised, and from the context it was likely that they would be imperative points in this context. Initially, the plan was to distinguish between “communicative reaches” and an “open-handed points”. However, this distinction was found not to be reliable, and thus the single category of “communicative reach was used”. Coders were asked to judge whether a behaviour was a non-social reach (i.e. solely reaching to obtain the object), a communicative reach, or point (i.e., with an extended index finger).

4.1.5 Pointing Gestures

4.1.5.1 Procedure

Pointing gestures were coded from the Out of Reach Object Task and Cloth Task (see 4.4.1.2). They were also coded from the free play period and the decorated room procedure, which are described in Chapter 2, section 2.3.2 (free play) and section 2.3.5 (decorated room).

CDI Question. The UK-CDI question that examines pointing behaviour is worded as follows: "Points (with arm and index finger extended) at some interesting object or event."

4.1.5.2 Behavioural Coding

An overview of the behavioural coding scheme for pointing gestures is provided in Table 4.5.

Table 4.5

Behavioural Coding Scheme for Pointing Gestures

Score	Description
2	The infant used an outstretched arm to direct E/M's attention towards some target. They either used an extended index finger or open hand, as long as the form and target of the gesture was clear (i.e. the arm and wrist were held straight towards a clear target). The infant must visually attend to both the target object and to the adult's face during the process.
1	The infant produced a possible or attempted pointing gesture, which lacked the clear form (such as the hand not being clearly held towards the target object, or the fingers being curled into a fist). Or, the infant produced a request gesture but did not visually attend to the object and E during this process.
0	The infant made no attempt at producing a pointing gesture, or produced no clearly relevant action.

Note. The full version of the coding scheme can be found in Appendix 4A.

Scores of "2" required an outstretched arm and index finger towards a clear target, combined with visual attention to both the target object and the adult. Scores of "1" were given when components of a pointing gesture were present, but either the form or coordination of actions was lacking some component(s). For example, if the index finger or hand was not clearly pointed towards the target, a score of "1" would be awarded (if the other conditions were met). Likewise, a pointing gesture with the appropriate form but lacking visual attention to the adult could only receive a "1".

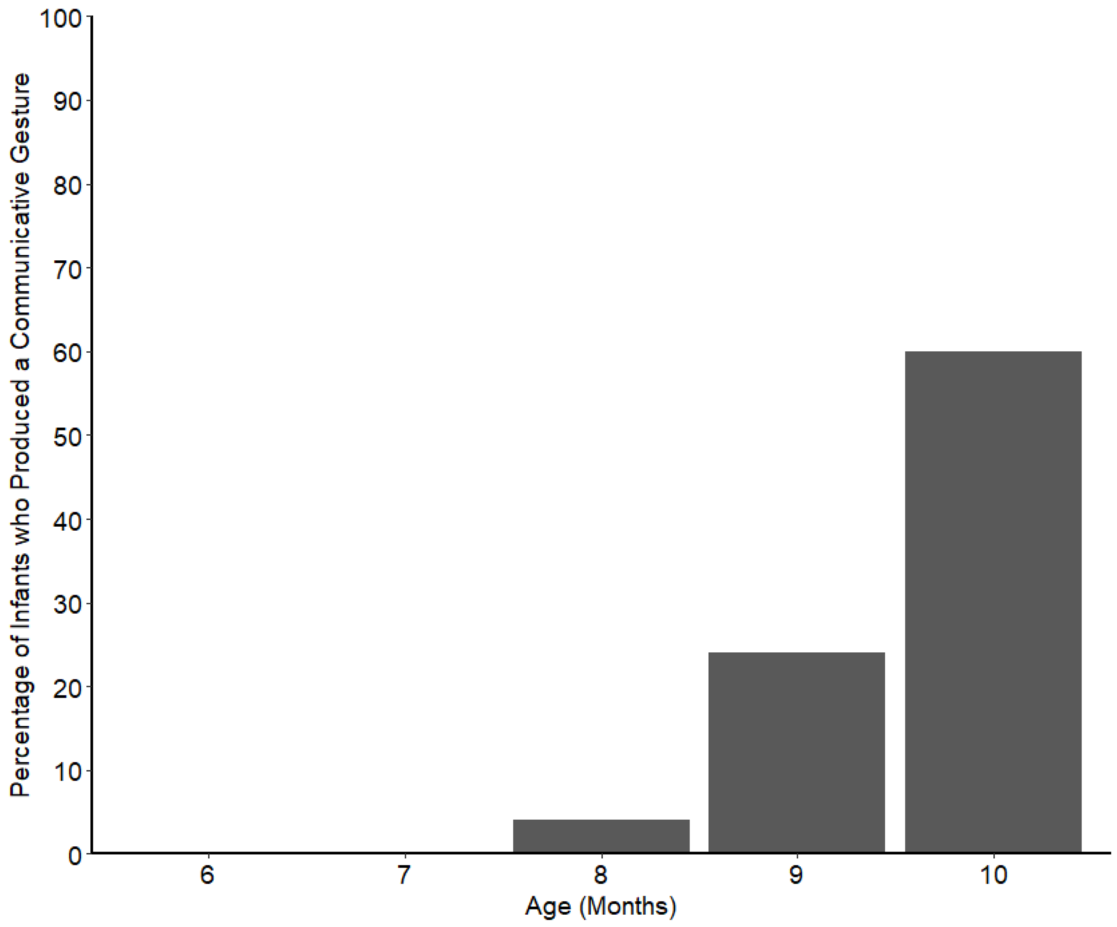
4.2 Results and Discussion

4.2.1 Overall Development of Communicative Gestures

The first set of results concerns the overall emergence of communicative gestures (scores of "2"). Figure 4.1 shows the cumulative number of infants who had shown a communicative gesture of any type at each month.

Figure 4.1

Percentage of Infants who had Produced a Communicative Gesture of any Type (Score of "2") by each Age Across all Tasks



The first gesture emerged at 8 months and the number of infants producing communicative gestures increased at 9 and 10 months. A majority of infants (15 out of 25, 60%) had produced at least one communicative gesture by 10 months. A GLMM was specified in order to examine whether a significant increase in communicative gestures occurred between any consecutive months. Age was entered as a categorical fixed effect, and participant as a random effect. The dependent variable was a binary outcome, communicative gesture production (0 for no communicative gestures across all tasks, 1 for a communicative gesture in any task (score of “2”)). The model used a binomial error structure and logit link function. The table of model coefficients can be found in Appendix 4B, Table 4B1. A Tukey’s HSD post hoc test on age revealed no significant difference in communicative gesture production between any two consecutive months.

4.2.1.1 Discussion

These results are in line with previous work on communicative gestures, which identifies these behaviours as starting to emerge at around 8 to 10 months (Bates et al., 1979; Cameron-Faulkner et al., 2015; Carpenter et al., 1998). The trajectory of emergence did not involve a significant increase between any consecutive months, indicating a gradual emergence.

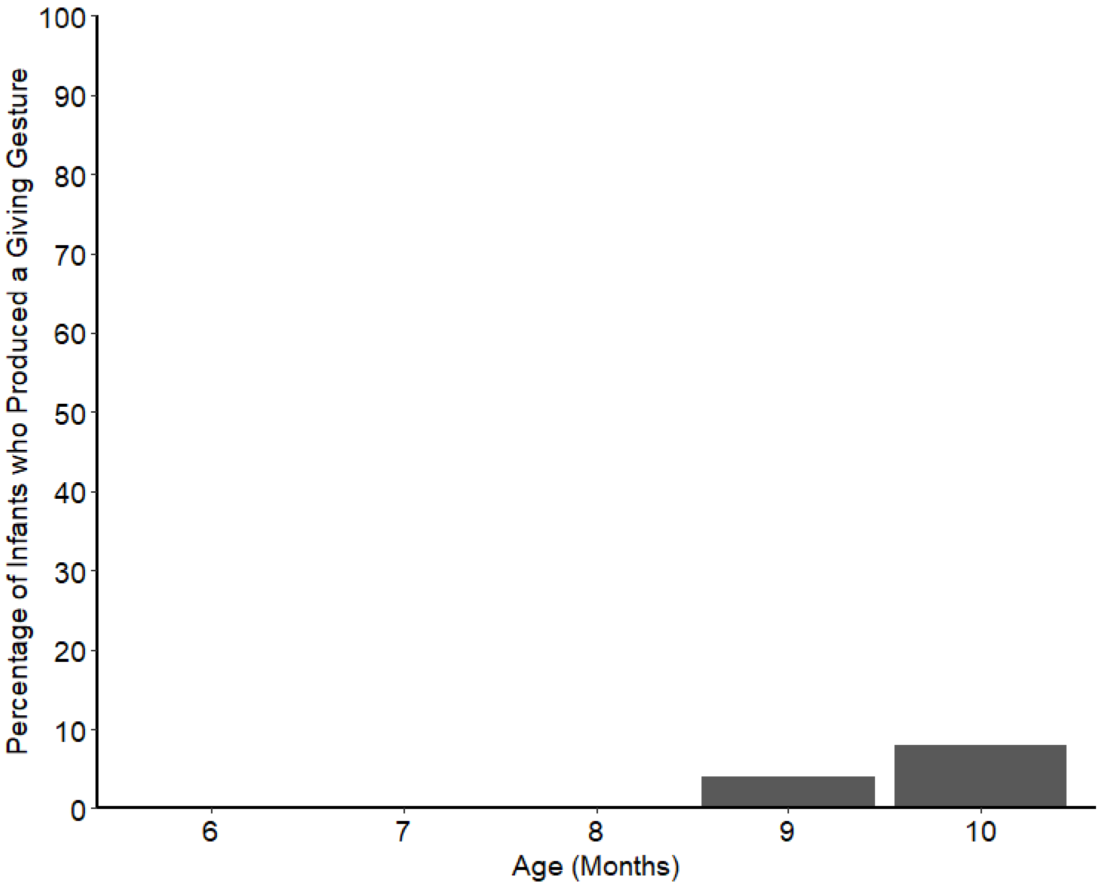
4.2.2 Giving Gestures

4.2.2.1 Results

The results demonstrating the emergence of communicative giving gestures (scores of "2") are displayed in Figure 4.2.

Figure 4.2

Percentage of Infants who had Produced a Giving Gesture (Score of "2") by each Age

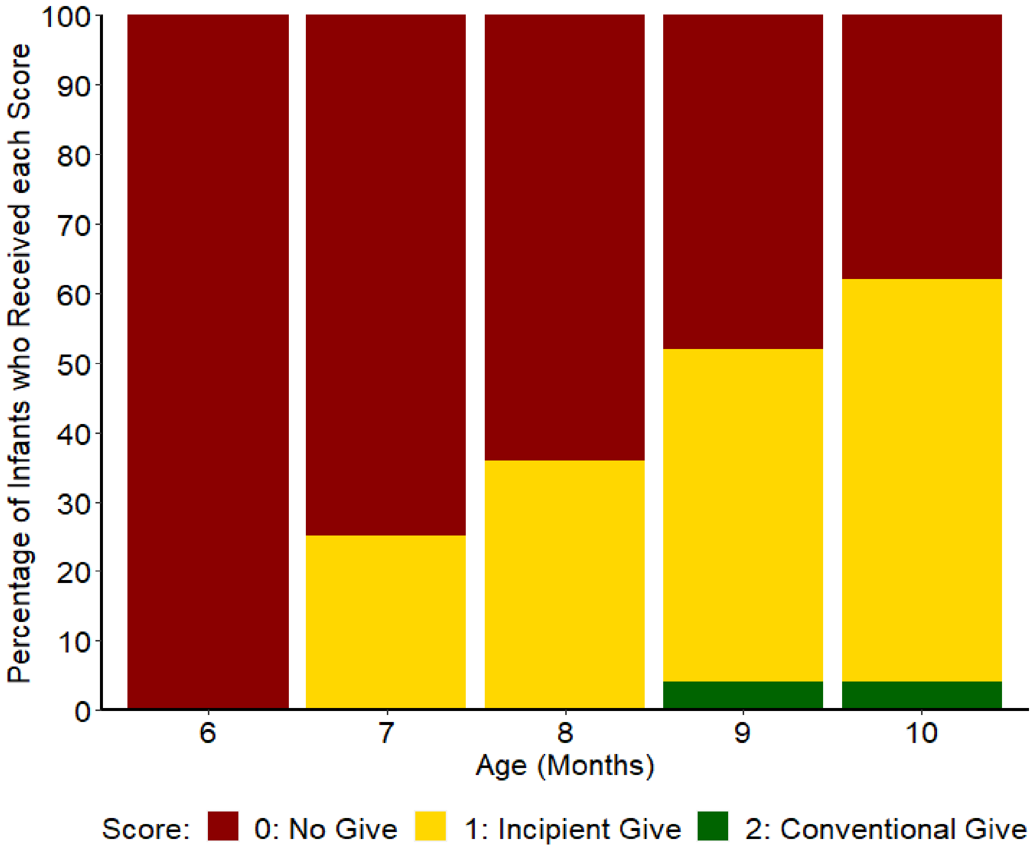


One infant produced a communicative giving gesture at 9 months (1 out of 25; 4%), and a second did so at 10 months (1 out of 25; 4%). It is worth noting that a number of other infants successfully produced a giving gesture that was conventional, but not clearly communicative (i.e., visually attending to both the object and E's face and hand during the process of giving the object). A further 6 infants successfully placed the target object into E's hand and released it in a controlled manner, 1 at 9 months (with 2 out of 25 (8%) having produced this behaviour by 9 months) and 5 at 10 months (with 8 out of 25 (32%) having produced this behaviour by 10 months).

Figure 2 presents the percentage of infants who received each score as their highest score for communicative giving gestures at each month.

Figure 4.3

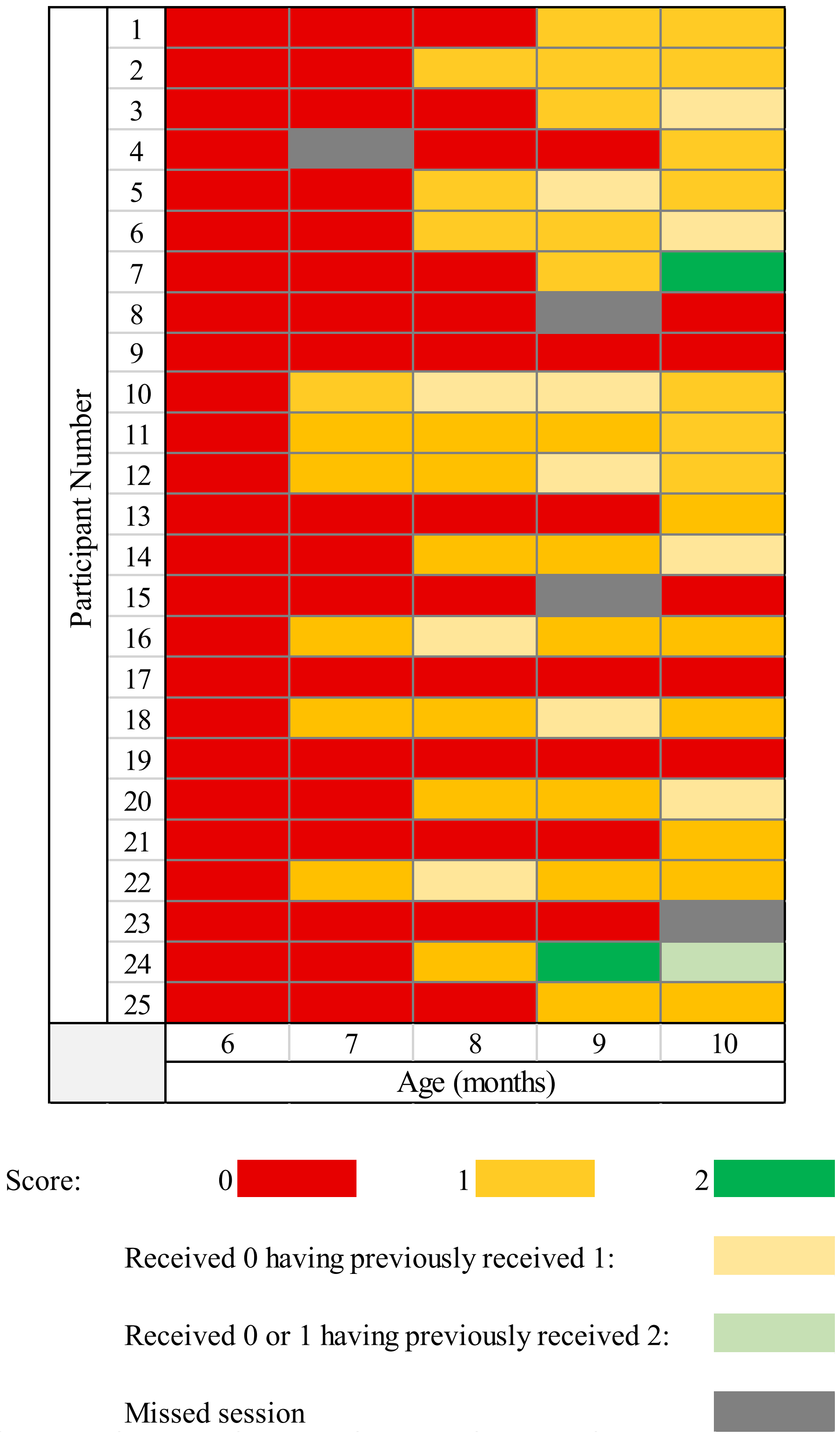
Percentage of Infants who Received Scores of "0", "1" or "2" as their Highest Score for Giving Gestures at Each Month



Focusing on incipient gestures, the first infants (6 out of 25; 24%) to produce incipient gives were 7 months old. Overall, 19 out of 25 (76%) of infants had produced at least one incipient giving gesture by 10 months. For individual participants' scores see Figure 4.4.

Figure 4.4

Individual Infants' Highest Giving Gesture Score at Each Month



Finally, the ordering of scores was assessed. As only 2 infants received a score of “2”, an analysis was not conducted for scores from the giving task. A further 17 infants had received a score of “1” but not a score of “2” during the period of observation. All respondents (n = 20) to the UK-CDI indicated that their infant was capable of producing giving gestures by 12 months, and we gave these infants a score of “2” for the analysis. Only those infants that had received at least a “1” by 10 months (i.e., did not only receive scores of “0”), and were confirmed to be capable of producing giving gestures by 12 months, were included. Of those infants, 15 out of 15 (100%) infants showed the pattern of “1” preceding “2”. This is significantly above chance level (binomial test, $p < 0.001$, 95% CI [0.78, 1.00]). If we assume that all 19 infants who received at least a “1” during the period of observation were eventually able to produce communicative giving gestures, 19 out of 19 (100%) would show this pattern (“1” preceding “2”). This is significantly above chance level (binomial test, $p < 0.001$, 95% CI [0.82, 1.00]).

4.2.2.2 Discussion

Overall, few infants produced communicative giving gestures, with only 2 infants being observed to produce these behaviours. These numbers are at least in part due to the restrictive criteria applied regarding eye-contact, as a total of 8 infants successfully gave E the target object, without visually attending to his face during this process. Drawing from the data collected at 12 months, it was found that scores of “2” were preceded by scores of “1” in a significant proportion of participants.

The majority of infants produced some kind of incipient giving gesture. There are at least two possible ways to interpret these incipient giving gestures. First, it is possible that infants did not have any understanding of E’s request and instead were interacting with E’s hand simply as a salient focal point for exploration. Even if so, in the context of give-and-take games, these behaviours may serve as interactional triggers for caregiver responses: as infants place the object, caregivers may encourage them to release it or simply take the object (Carpendale et al., 2021). This in turn facilitates the infants' transition from a passive to an active, initiating participant (Bruner, 1977).

Second, there are alternative plausible explanations which ascribe varying degrees of social understanding to the infants. For example, after having participated in previous interactions with caregivers in which caregivers had taken the objects from infants themselves (Bruner, 1977, 1983; de Barbaro et al., 2013), infants might mistakenly have believed that E wanted them simply to put the object on his hand, expecting that he would take it himself once they did this. We observed that several infants at 9 and 10 months looked up at E's face, sometimes with a smile, after initially placing the object on his hand without releasing it, suggesting that the placing was what they thought they were expected to do. It might thus be the case that at least some infants engage in "allowing-to-take" before actual giving.

In other cases it seemed clear that infants were actually trying to give the object, but did not succeed because of various limitations – most commonly motor limitations that prevented them from releasing the object in a controlled manner once it was placed on E's hand. For example:

> Participant 14, 9 months: E requested the object. The infant, looking at E's hand, lowered the object onto it, holding it there for a few seconds. He smiled broadly, making eye contact with E. He then released all his fingers from the object, and it fell off E's hand and onto the table. E repeated the request twice more, and at the third request, the infant again placed the object onto E's hand. This time, he closed all his

fingers and squeezed the object, which caused it to fall out of his hand, bounce off E's hand, and fall onto the table.

That the infant placed the object onto E's hand and released his fingers from the object plausibly indicates some intention to give the object to E. Other possibilities for limitations are that infants may have struggled to inhibit maintaining possession of the object, or may have failed to understand that giving requires one not just to release the object but also to leave the object in the other's hand. For example, one participant (Participant 10, 10 months), having seemingly struggled for several seconds to release the object onto E's hand (including removing his fingers from the object and sliding his hand off the object), retrieved the object immediately after releasing it onto E's hand.

These observations again suggest the possibility that these gestures, and the social understanding underlying them, emerge in a gradual manner, rather than in an all-or-nothing switch from no capacity or understanding to a mature capacity and understanding. Further observations provide evidence that infants may have had an understanding of E's request, and object transfer in general, before they produced conventional giving gestures. For example, some infants dropped the object in front of them and looked up at E (e.g. Participant 5, 9 months), or threw it towards E or E's hand after making eye-contact with him (e.g. Participant 2, 9 months), which again may have been with the expectation that E obtain the object. In one case (Participant 24, 10 months), the infant grasped E's hand and moved it towards the object, which was on the table. This is potentially a "hand-taking gesture" (Gómez, 2015), encouraging E to take the object himself, and in that case the infant ultimately did give E the object conventionally by the end of the task. The reverse also occurred: an infant (Participant 3, 9 months) grabbed E's hand and moved it away from the object, which may have been evidence that she understood but rejected his request.

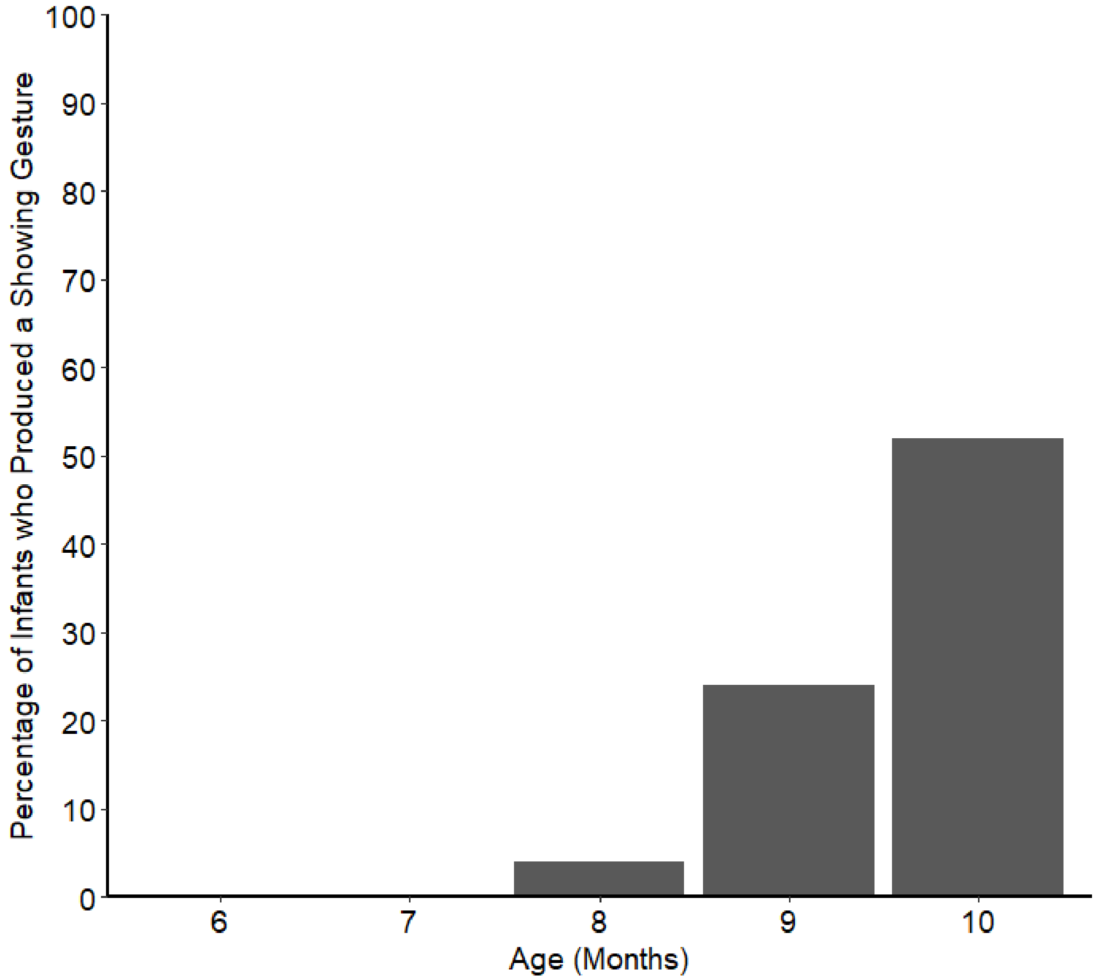
4.2.3 Showing Gestures

4.2.3.1 Results

First, the results demonstrating the emergence of showing gestures (scores of "2") are reported. These are displayed in Figure 4.6.

Figure 4.6

Percentage of Infants who had Produced a Showing Gesture (Score of "2") by each Age

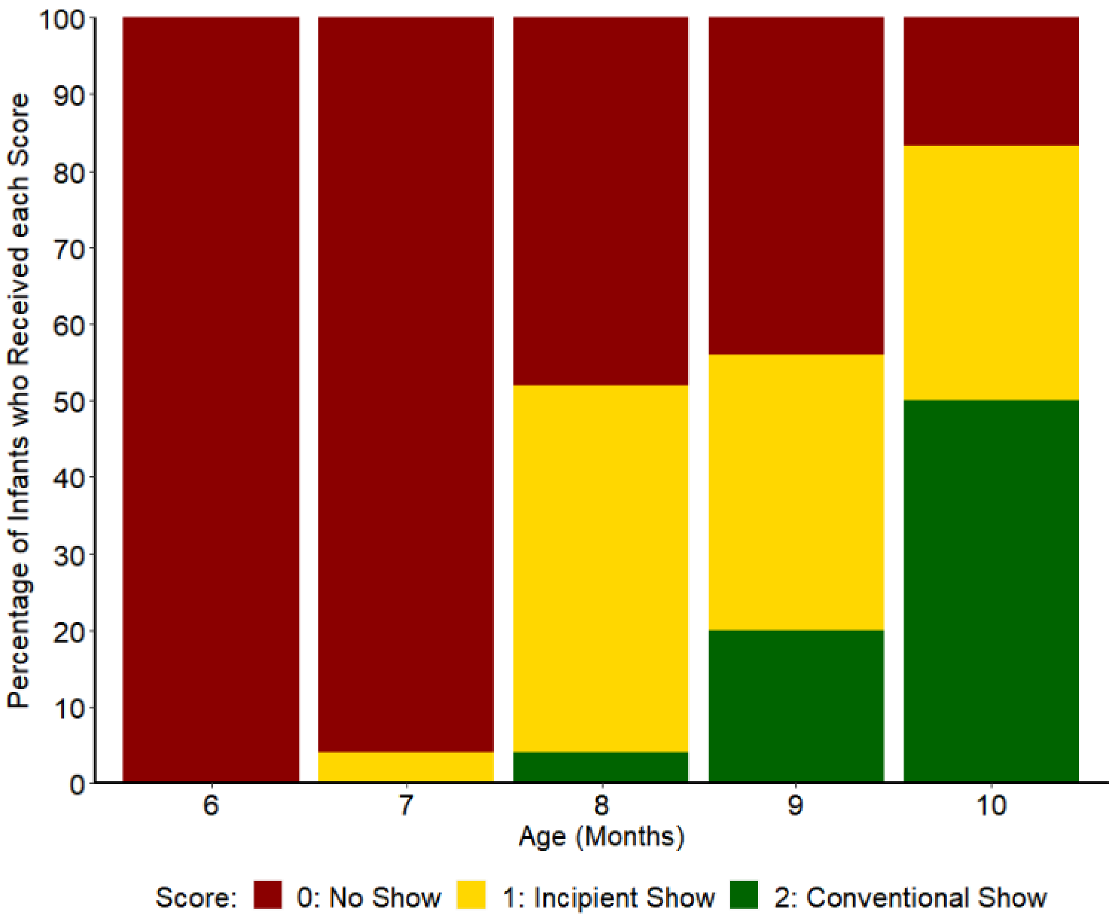


The first infant to produce a conventional showing gesture was 8 months old, and the number of infants producing showing gestures then increased steadily, with 13 out of 25

(52%) infants having produced a conventional show at least once by 10 months. A GLMM was specified in order to examine whether a significant increase in showing gestures occurred between any consecutive months. Age was entered as a categorical fixed effect, and participant as a random effect. The dependent variable was a binary outcome, showing gesture production (0 for no showing gestures across all tasks, 1 for a showing gesture in any task (score of “2”)). The model used a binomial error structure and logit link function. The table of model coefficients can be found in Appendix 4B, Table 4B2. A Tukey’s HSD post hoc test on age revealed no significant difference in showing gesture production between any two consecutive months.

Figure 4.7

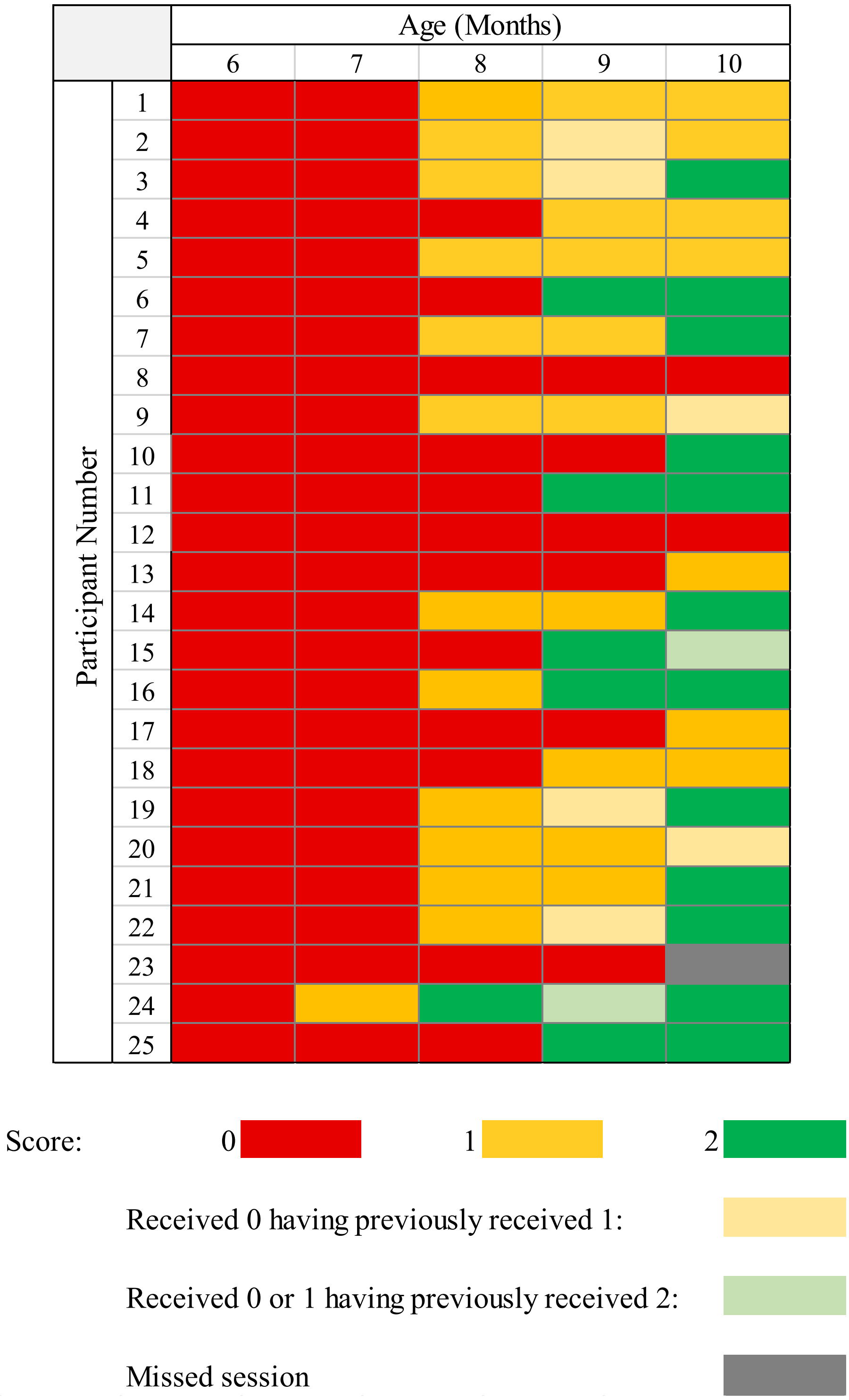
Percentage of Infants who Received Scores of "0", "1" or "2" as their Highest Score for Showing Gestures at Each Month



Focusing on incipient gestures, the first infant to produce an incipient show was 7 months old. Overall, 18 out of 25 (72%) infants had produced at least one incipient showing gesture by 10 months. For individual participants' scores see Figure 4.8.

Figure 4.8

Individual Infants' Highest Showing Gesture Score Collapsed Across Tasks at Each Month



Again, there was variation in how long and how consistently infants produced the candidate incipient gesture, with some producing the behaviour in 1 or 2 consecutive months before producing the conventional form, and others producing a conventional showing gesture having never produced the candidate incipient gesture.

Next, the ordering of scores was assessed. First, cases in which a conventional showing gesture was observed during in-person assessments were examined. Out of those infants that produced a conventional showing gesture during the study (i.e. received a score of "2", n = 13), 8 out of 13 (64%) of infants displayed the pattern of receiving a score of "1" prior to a score of "2". The occurrence of this pattern are not significantly above chance levels (two-tailed, p = 0.42, 95% CI [0.35, 0.87]).

A further 9 infants had received a score of "1" but not a score of "2" during the period of observation. All respondents to the UK-CDI (n = 20) indicated that their infant was capable of producing showing gestures by 12 months, and we gave these infants a score of "2" for the analysis. Only those infants that had received at least a "1" by 10 months (i.e., did not only receive scores of "0"), and were confirmed to be capable of producing showing gestures by 12 months, were included. Of those infants, 14 out of 19 (74%) infants showed the pattern of "1" preceding "2". This is not significantly above chance levels (two-tailed, p = 0.06, 95% CI [0.49, 0.91]). If we assume that all infants who received at least a "1" during the period of observation were eventually able to produce showing gestures, 17 out of 22 (77%) would show this pattern ("1" preceding "2"). This is significantly above chance levels (two-tailed, p = 0.02, 95% CI [0.55, 0.92]).

4.2.3.2 Discussion

Infants' production of showing gestures was in line with previous work (e.g. Bates et al., 1979; Cameron-Faulkner et al., 2015), with the abilities starting to emerge between 8 to 10 months in the majority of cases. There was some evidence that scores of "1" reliably preceded scores of “2”, but only when calculating based on infants’ assumed developmental path.

The majority of infants (72%) produced an incipient showing gesture. The key question is how to interpret these behaviours. There are at least two possible interpretations, each ascribing different capacities to the infants. The first interpretation is that these behaviours are non-communicative, and are either unrelated to conventional shows, or potentially serve as interactional triggers that elicit relevant caregiver responses. The second interpretation is that these behaviours are communicative, but not yet conventional. On this reading, the infants intend to show objects, but cannot yet do so conventionally due to limited motor and/or cognitive capabilities. It is possible that both interpretations might be correct and involved in the pathway toward conventional showing gestures, just at different moments in development. It is also possible that different infants may follow different developmental paths.

Under the first interpretation, the behaviours may be coincidental, exploratory or arousal-based: infants were simply playing with the object, or got excited by the situation, and happened to move in a way that resembled a showing gesture. One could thus conclude that these behaviours are unrelated to showing gestures, or are only related to the extent that they involve similar motor capacities that must be established to produce the conventional behaviour. On some accounts, it is only after infants have undergone relevant cognitive developments (such as means-ends understanding (Bates et al., 1979) and understanding of attention and intentions (Tomasello, 1999)) that they can start to produce intentionally-communicative gestures, suggesting that behaviours that occur prior to this understanding are not relevant. However, even if these behaviours are initially non-communicative, it does not preclude them from playing a role in the developmental pathway towards showing (Carpendale & Carpendale, 2010; Carpendale et al., 2021). Even unintentional behaviours, as long as they are show-like, could elicit a positive response from caregivers, which in turn would encourage infants to engage in further instances of these behaviours, providing a cycle of learning from which infants could gradually become aware of the effects of these actions (Carpendale et al., 2021).

A second way of interpreting incipient showing gestures is that they are communicative, and that infants intend to draw the adult's attention to the object; it is just that they do not yet do this in a conventional way. In these cases, infants manifest a burgeoning capacity to engage in showing that is limited because the infants have limited motor control that prevents them from producing the conventional form and/or do not yet fully understand the optimal form of a conventional show (Bates et al., 1979). For example, in support of this interpretation, in the current study there were several cases in which the behaviour almost met the criteria for a conventional show, but did not, because the object was not held stably in place, e.g.:

> Participant 1, 9 months: The infant raised the object to the side of her head, making eye contact with E. She brought her arm forward so the object was held briefly (< 1 second) towards E's face, before moving the toy up and down and smiling. Whilst shaking the toy, she attended to it briefly, and twice the up and down movement was paused so the toy was only briefly held stable in front of E.

> Participant 4, 9 months: After the mother commented on a book the infant was holding and looking down at, the infant looked up at the mother, smiled, laughed, and raised the book to his head height, towards his mother's face, and lowered it, all in a single arcing motion. The mother smiled and touched the book, saying, "Want me to do it?", but the infant continued to hold it.

There are several features of these examples that provide support for the thesis that these are not simply coincidentally show-like movements, but rather attempts to bring the object into E's visual attention communicatively. In each case, there is visual attention to both the object and the adult, and a smile produced alongside the action. The motion is towards the adult's face, either with a shaking motion or continuous movement. In the second case, the mother understood the act as bringing the object into her attention (though seemingly as a request for help). In each case, it is plausible that the infants were simply limited by their motor skills; they attempted to produce an intentional show, but lacked the coordination or strength to hold it stably towards the adult.

Other observations suggest that at least some infants might gradually incorporate objects into engagements as they transition from engaging others communicatively in a dyadic manner, to doing so triadically. Consider the following example:

> Participant 2, 8 months: The infant grasped the object, without looking at it. He then looked up to his mother, smiled, and held the object up and out in front of him, at about his head height. He held the object stable for several seconds as he rocked his body back and forth, seemingly in excitement. As he did so, his mother said, "What's that? What's that?" in a high-pitched tone. Then the infant lowered the object.

In this case, the infant consistently looked at his mother and smiled at her, without visually attending to the object. This suggests that he was communicatively engaging with her in a dyadic manner, rather than drawing her attention to the object. However, his raising and holding stable of the object was salient, and otherwise very much resembled a conventional show; it was clearly towards the mother, and held stable for several seconds. It is relevant here that his raising of the object resulted in an excited response from the mother – one that likely would not have occurred without the inclusion of the object in the act. It is possible that this behaviour is declarative in the older sense of the word initially used by Bates and colleagues (Bates et al., 1975): the use of an object to draw attention to oneself (see also Boundy et al., 2019 for a discussion of this behaviour). Alternatively, cases such as these may represent “transitional forms” between dyadic and triadic engagements, in that it is not clear that the infant was drawing the adult’s attention to the object, but the act of raising the object was salient within the engagement. On this view, objects are gradually included within the engagement, as infants become increasingly aware of the role they can play in interactions, and as caregivers increasingly react to the inclusion of objects by infants (Moll, et al., 2021).

Infants who are motivated to engage another person with an object may require experience to learn the conventional positioning of an object when showing it – a position which is optimal spatially but also, critically, with regard to eliciting a social response. For example, some infants (e.g. Participant 15, 9 months) held the object away from their body and kept it stable, with gaze alternation between object and adult, but not clearly up and towards the adult’s face. However, other features that have been used to identify intentionally communicative acts, such as waiting for a response and persisting with the act when needed (Bates et al., 1979), were not always present in these types of examples, so we cannot be sure that they were intentionally communicative (though note that with cases such as Participant 2, 8 months, above, neither of these features was necessary as the mother immediately took the act to be communicative). It may be that an infant can often succeed in getting another to attend to an object with a suboptimal (e.g. not clearly directed, unstable, with no response waiting) or nonconventional show, but it is less clear and thus less likely to elicit a response than a conventional show (Boundy et al., 2016).

A final methodological point to highlight is the influence of the properties of the object. When infants had larger objects, or objects with protruding or dangling elements, it was sometimes less clear whether they were showing the object, for example when they held a dangling element, e.g. a leg of a soft toy, with the main body of the object hanging below (e.g. Participant 13, 10 months). Furthermore, the size and/or weight of the object may have been the source of some of the problems with stability. A unique challenge of showing gestures (compared to, for example, pointing) is that infants actively control the position of the object themselves, and thus the objects' size and shape play a role in the form of the showing gesture that is produced. Any multimodal properties the object has can also be relevant; for example, sometimes infants might share the noise made by an object, the movements it can make, or its tactile properties. A possible avenue for future research is to explore infants' capacity to show these different properties of objects. However, if the focus of a study is solely on infants' production of conventional showing gestures, the best objects to use, in our experience, are small, compact, lightweight, easily graspable, and silent.

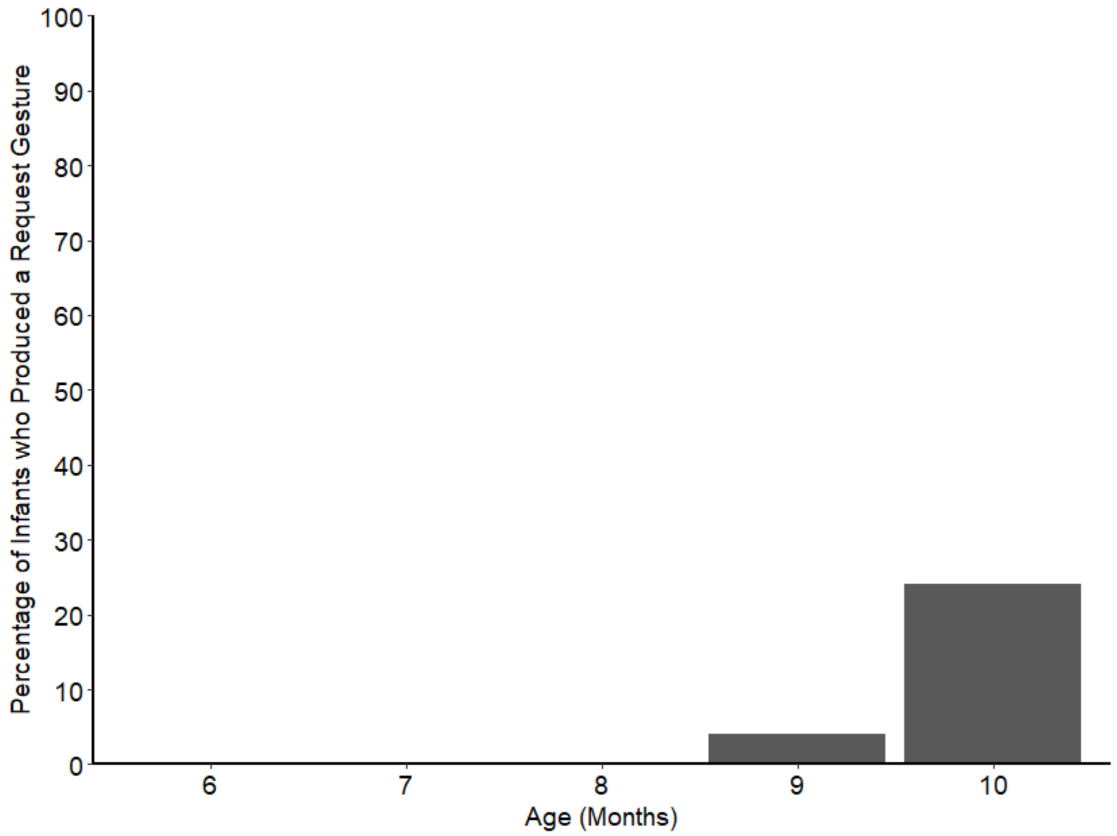
4.2.4 Request Gestures

4.2.4.1 Results

First, the results demonstrating the emergence of communicative requesting gestures (scores of "2") are reported. These are displayed in Figure 4.10.

Figure 4.10

Percentage of Infants who had Produced a Request Gesture (Score of "2") by each Age



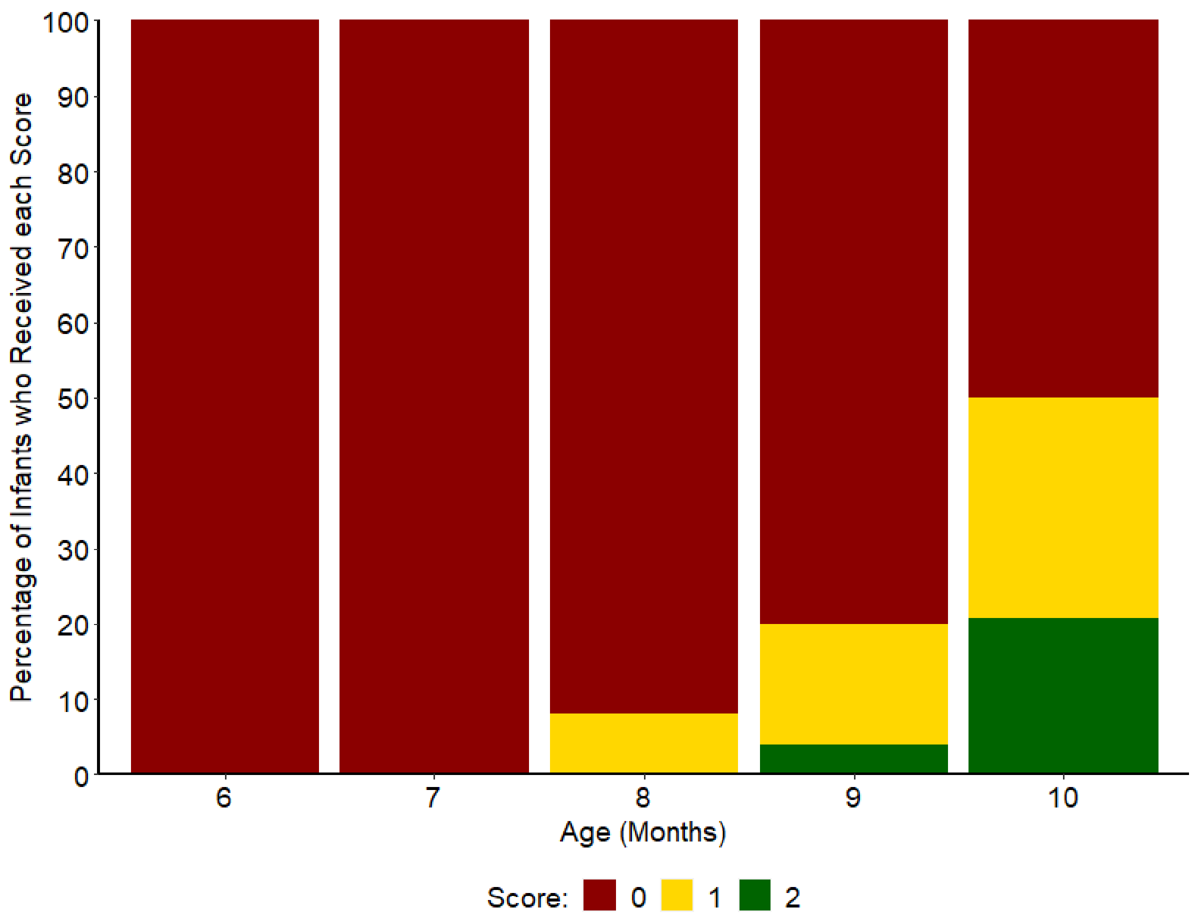
The earliest request gestures appeared at 9 months, with only 6 out of 25 (24%) of infants producing a request gesture of some kind by 10 months. Four out of 25 (16%) produced a proximal request, and 3 out 25 (12%) produced a distal request, with 1 child producing both. Because of the low numbers of infants producing requesting gestures, a

McNemar's test was used to assess significant changes in production between consecutive months. No significant increases were found between any two consecutive months.

To investigate the development of communicative requesting gestures, from incipient to conventional forms, we next examined scores of "0", "1" and "2". Figure 4.11 displays the highest score received by participants at each session.

Figure 4.11

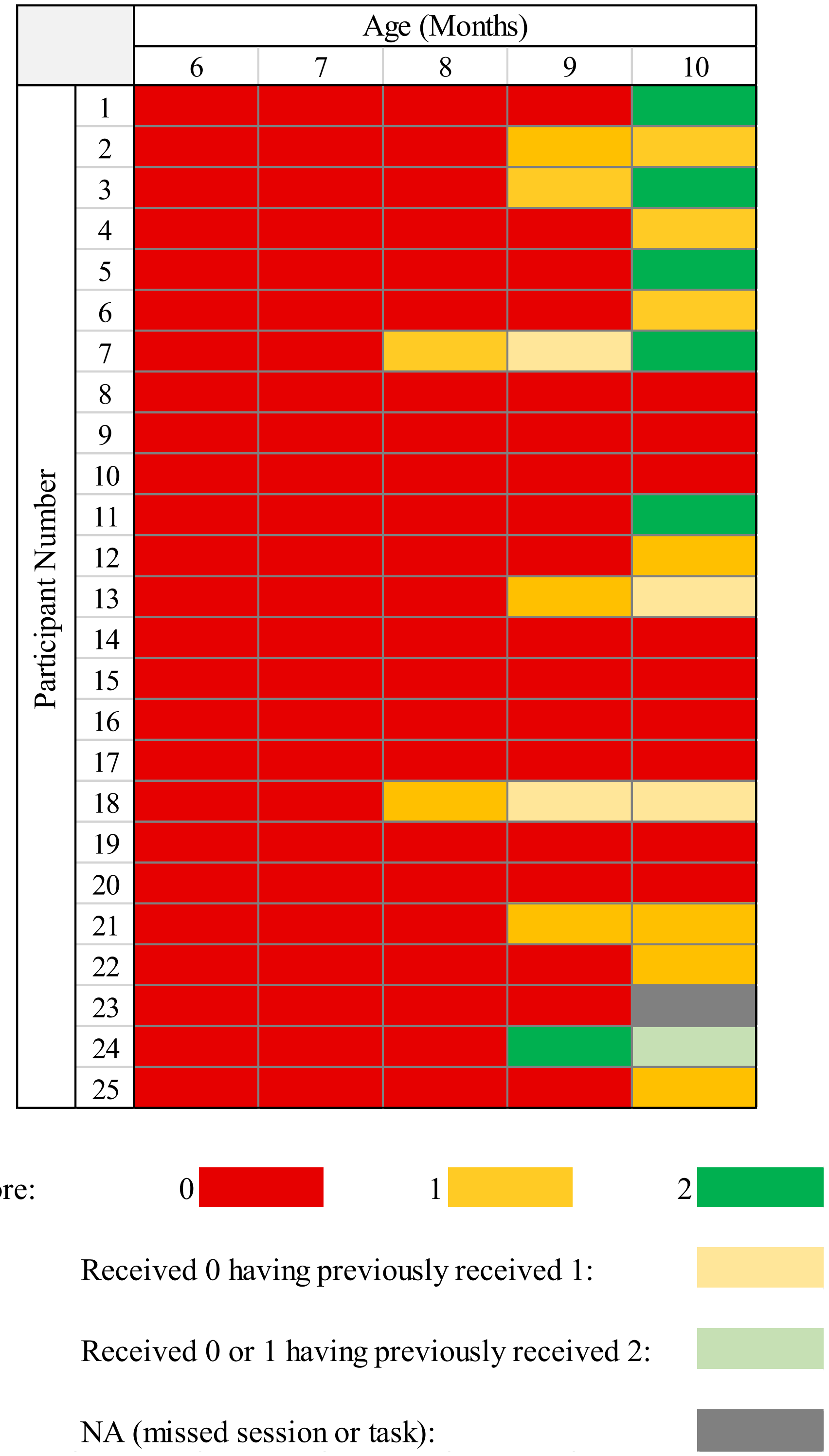
Percentage of Infants who Received a Score of "0", "1" or "2" as their Highest Score for Request Gestures at Each Month



Infants first produced incipient requesting gestures at 8 months (2 out of 25; 8%). Figure 4.12 provides a visualisation of the ordering of these scores from month to month.

Figure 4.12

Individual Infants' Highest Request Gesture Score Collapsed Across Tasks, Cumulatively for Each Month



Next, the ordering of scores was assessed. First, cases in which a conventional requesting gesture was observed during in-person assessments were examined. Out of those infants that produced a conventional requesting gesture during the study (*n* = 6), 2 out of 6 of infants (33%) displayed the pattern of receiving a score of "1" prior to a score of "2". This was not significantly above chance levels (two-tailed, *p* = 0.69, 95% CI [0.04, 0.77]). A further 9 infants had received a score of "1" but not a score of "2" during the period of observation. Of the respondents to the UK-CDI (*n* = 20), 17 indicated that their infant was capable of producing request gestures, and we gave these infants a score of "2" for the analysis. Only those infants that had received at least a "1" by 10 months, and were confirmed to be capable of producing requesting gestures by 12 months, were included. Out of the infants, 7 out of 10 (70%) showed the pattern of "1" preceding "2". This was not significantly above chance levels (two-tailed, *p* = 0.55, 95% CI [0.31, 0.89]). If it assumed that all infants who received at least a "1" during the period of observation were eventually able to produce communicative request gestures, 11 out of 15 (73%) would show this pattern ("1" preceding "2"). This is not significantly above chance levels (two-tailed, *p* = 0.12, 95% CI [0.49, 0.92]).

4.2.4.2 Discussion

Requesting gestures were just beginning to emerge at around 9 to 10 months in the sample. It was not clear whether the identified incipient gestures preceded the emergence of conventional requesting gestures. This may have been due to the overall low numbers of infants identified producing incipient gestures, as well as the approach taken to collapse the different kinds of requests together.

Future research with a slightly older population may provide clearer evidence as to whether the proposed incipient request behaviours precede the emergence of request gestures.

Because of low numbers, we collapsed proximal and distal requests together for the analysis, viewing both as indexing an ability to request objects. However, it may be the case that infants can be proficient in one of these tasks and not the other. Both in terms of conventional, communicative requests, and putative incipient requests, assessing infants' capabilities with older infants may provide clearer insights into infants' developing requesting gestures.

Finally, it is worth noting a behaviour that occurred often, that we did not code for systematically. This was banging on surfaces, such as the table or the transparent box. We did not include this behaviour as in the experimental set up we employed as it was difficult to discern whether this occurred due to excitement or frustrations, rather than as a communicative act. However, it was something that occurred frequently during these procedures (as well as being noted by mothers, as discussed later in this chapter, section 4.3). Thus, this behaviour may be one worth exploring in future investigations of incipient requests.

4.2.5 Pointing Gestures

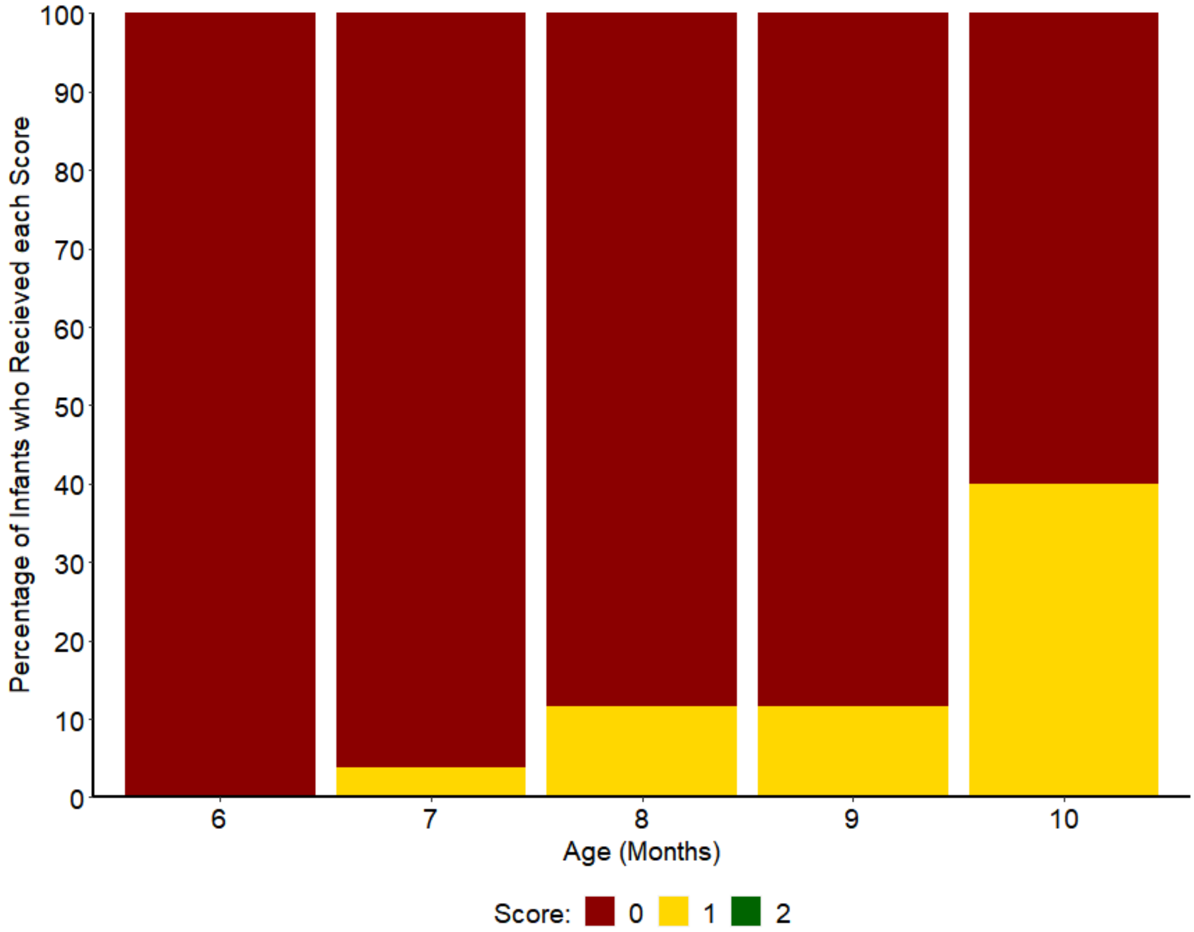
4.2.5.1 Results

Over the course of the study, we did not observe any infants producing a communicative pointing gesture (a score of "2"; an extended an arm and index to a clear target with visual attention to the adult and target object).

To investigate the development of giving, from incipient to conventional forms, we next examined scores of "0", "1" and "2". Figure 4.13 displays the highest score received by participants at each month.

Figure 4.13

Percentage of Infants who Received a Score of "0", "1" or "2" as their Highest Score for Pointing Gestures at Each Month

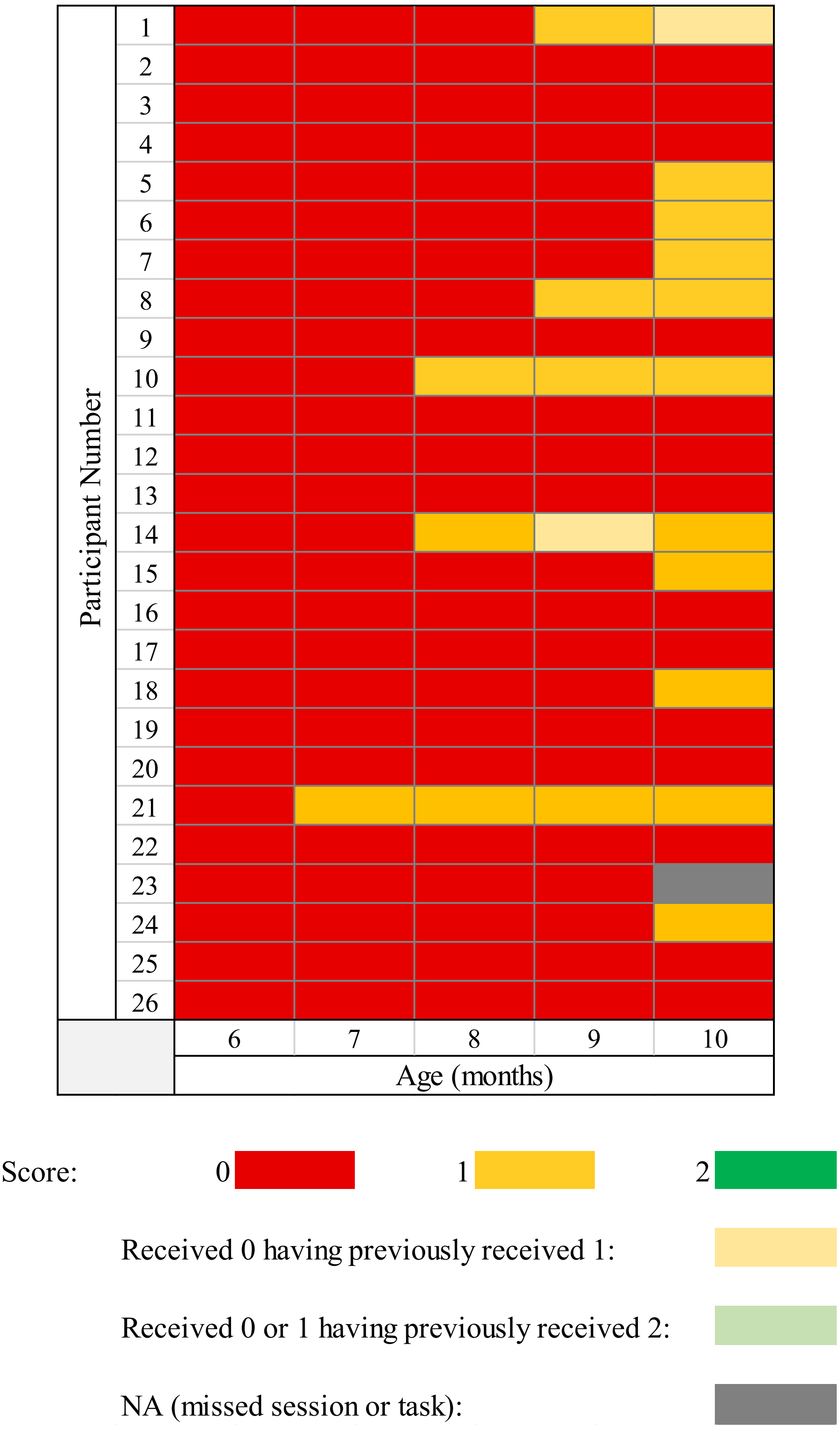


Scores of "1"were first awarded at 7 months of age. By 10 months, 11 out of 26 infants (42%) had received at least one score of "1" during the period of observation.

Figure 4.14 provides a visualisation of the ordering of "0" and "1" scores for individual infants.

Figure 4.14

Individual Infants' Highest Pointing Gesture Score Collapsed Across Tasks, Cumulatively for Each Month



Of the respondents to the UK-CDI (*n* = 20), 16 (80%) indicated that their infant produced pointing gestures, and we gave these infants a score of "2" for the analysis. Only those infants that had received at least a "1" by 10 months, and were confirmed to be capable of producing pointing gestures by 12 months, were included. Of those infants, 9 out of 9 infants (100%) showed the pattern of "1" preceding "2". If we assume that all infants who received at least a "1" during the period of observation were eventually able to produce pointing gestures, 10 out of 10 (100%) would show this pattern ("1" preceding "2"). However, these results must be understood with particular caution given the number of participants (*n* = 14, 56%) who received only "0" during the study.

4.2.4.2 Discussion

No infants produced a communicative pointing gesture in the course of the study. This may partly be because we required visual attention to both the target and the interaction partner, which ruled out cases that had the conventional gestural form but did not involve a look to the mother. However, pointing gestures generally emerge later in development than the other behaviours examined (Bates et al., 1979).

Of the infants in the study, 11 out of 25 (44%) received a score of "1", and in all cases meeting the inclusion criteria, this preceded the infant being capable of communicative pointing gestures. However, given the number of infants not producing any kind of gesture (incipient or conventional), these results are somewhat limited.

Those incipient gestures that were produced appeared primarily to be points-for-self, with the infant extending their arm towards some target either with an open hand, or extended index, but without looking to their mother, behaviours that have been highlighted in previous work (e.g. Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018). However, one feature of these behaviours that has not previously been highlighted were the varieties of hand, finger and wrist orientation that were observed. Figure 4.15 displays the different kinds of positions that were observed amongst the participants.

Figure 4.15

Hand and Finger Positions for Incipient Pointing Gestures

Note. A: Extended index finger (without eye contact). B: Open hand with palm pointing towards the ground. C: Open hand with palm pointing towards the target. D: Closed fist with palm pointing towards the ground. E: Closed fist with palm pointing to the side. F: Single-handed wave towards the target. G: Double-handed wave towards the target. H: Open hand with palm pointing towards the target, combined with rotation of the wrist.

Whilst the conventional extended index gesture was observed, there were a range of other actions. Different infants used a mix of strategies, both in terms of the way they positioned their hand (e.g. the direction of the palm, an open hand or a closed fist) and whether they moved their arm or hand (e.g. by waving, opening and closing their hand, or rotating their hand at the wrist). It is not clear quite what these gestures were communicating, or whether they were indeed communicative. However, they were all clearly directed towards some target, suggesting they were at least actions for the self.

Future work could explore the significance of these varied point-like gestures at this age, before conventional communicative pointing gestures have emerged. Pointing elicitation paradigms (e.g. Liszkowski et al., 2004) could be used to examine whether infants produce these behaviours in the same sorts of contexts as they do later communicative points, in order to examine whether they may in fact be a form of communicative gesture. Similarly, naturalistic studies in the home context could seek to identify more examples of these behaviours, adding to previous work that has examined different forms of index pointing in the home context (Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018). Given that there was significant diversity amongst these behaviours, it may be that these behavioural forms are idiosyncratic, emerging in the context of each caregiver-infant dyad before developing into the canonical pointing gesture. If so, studies in the home context may be best placed to draw out these behaviours. Regardless, these examples suggest that there is still more to be explored in the developmental origins of pointing.

4.3 Maternal Interview Responses

Mothers, too, reported incipient gestures. For example, in response to E's question about whether infants produced showing gestures, there were reports of the object not being held stable (examples are edited slightly for clarity):

> Participant 7, 9 months: "…the occasional sort of flail that looks slightly deliberate, or more like a pause in play, and also getting eye contact."

Participant 16, 8 months: "I suppose sometimes when he's banging the blocks he'll stop and he'll kind of go like this [*raises a fist and shakes it*] with his hand towards you. But I don't know if he is or not."

And nonconventional shows:

Participant 5, 10 months: "He'll sometimes throw it. I feel like he throws it at me."
Participant 6, 9 months: "Just holds it right up to your face."
Participant 11, 10 months: "Yeah… basically she'd just bring me something, like a 'cool' Kleenex, she'll just put it on your lap."

Similarly, for giving there were reports of it not being controlled:

Participant 7, 10 months: …occasionally I can get her to give me the spoon. Mostly, she drops it, but sometimes she'll actually put it in my hand.

Participant 13, 9 months: "No I don't think so, no. I think she maybe tries to. But, I don't think it has been that controlled just yet."

And reports of nonconventional gives:

Participant 15, 10 months: "…giving somebody something else he hasn't quite mastered, but he'll kind of drop something; he'll have it, and then will drop it and look at you, and that's almost his way of saying 'Hey look!'"

In the majority of responses relevant to requests, mothers described either vocalisations, reaching, or pointing. However, one behaviour that was mentioned as a form of non-conventional requesting was bashing on a surface:

Participant 7, 10 months: "She has on one occasion, when I didn't give it to her, smacked the table and grunted."

Participant 8, 8 months: “If she wants a toy or something on the table, she starts banging on the table and she looks at me.”

Participant 25, 8 months: “Sometimes she’ll actually bash in order to get an item.”

These behaviours were not considered as possible incipient requests due to the challenge of identifying whether the infant was bashing the table as a request, or simply as an exploratory or enjoyable action.

Parents that reported behaviours related to pointing identified similar behaviours to those that have previously been discussed in previous work on the origins of pointing. Index-finger exploration was frequently identified as an early form of attention and interest, with a number of mothers describing this behaviour as “pointing”. Furthermore, caregivers also highlighted behaviours such as pointing-for-self, or other points with no clear target (Kettner & Carpendale, 2018):

Participant 1, 11 months: “She was babbling and pointing as she ‘talked’, I don't know the target but she was looking in the direction of where she was pointing.”

Participant 10, 11 months: “He began to point at me and my partner when we were across the room. It seemed more as though he was noticing us rather than pointing at something he wanted or showing us to others.”

Participant 11, 11 months: “At first it was general pointing without a concrete target, but slowly developed to pointing at specific things.”

In the cases of incipient and nonconventional gestures, it appears that mothers often viewed these as de facto instances of the gesture, despite them being nonconventional. This suggests that mothers may respond not only to the form of the gesture, but also when they believe the infant is demonstrating a particular communicative intention (e.g., to show or request an object.) This intention may be inferred through infants’ use of gaze alternation, and the context, and also when the relevant interactional outcome (e.g. object transfer) is achieved, regardless of the gesture's conventionality. Conventionality may then result at least in part from mothers' increasing standards regarding what they respond to (Zeedyk, 1997), combined with the infant interacting with members of the wider of community, who would be more likely to understand and respond to conventional rather than idiosyncratic gestural forms.

A further noteworthy feature of the mothers' comments is that there was often ambiguity between showing and giving, though this was less common in later assessments (i.e. at 11 and 12 months of age). Previous work has highlighted that whether an infant's initial act of holding out an object resolves as a show or a give is often an outcome of a dynamically unfolding social situation (Cameron-Faulkner et al., 2015). Both caregivers and researchers can find it difficult to tell whether infants intend to show or give an object (Boundy et al., 2016; Dimitrova et al., 2015). Often, mothers responded to the interview questions about showing with a response that involved the infant transferring the object to the mother (e.g. Participant 11, 10 months). In other cases, mothers explicitly reflected on the difficulty in interpreting their infants' potential showing or giving behaviour. For example, in response to a question about showing, some mothers said:

> Participant 18, 8 months: "I think he is. He starts doing the bashing that he does with everything some days, but then he'll sort of catch your eye and hold things. He seems to be holding things up and he knows that if he holds certain toys like that I'll take them from him and join in and play with him. So he certainly seems to, whether or not he's meaning to."

> Participant 21, 10 months: "With showing… I actually grab it [*mimes grabbing*] [saying,] 'Oh, thank you!' I'm not sure if she actually wants me to take it, but she does hold it towards me. Not always, though."

These examples suggest that at these ages, sometimes the specific functional outcome is less important than the engagement with the mother. It has been suggested that infants at this age may have no social intentions and are simply carried along by the responses of the caregiver (e.g. Boundy et al., 2016). However, it may also be the case that infants are simply open to whatever way the interaction unfolds, and only later become more particular about their specific intention being understood, perhaps because they better understand the consequences of different functional outcomes (Carpendale et al., 2021).

4.4 General Discussion

This chapter makes a novel contribution to the literature on gestural development. First, it provides longitudinal data, at relatively closely-spaced intervals, on infants' gestural communication across a range of different gestural types. This allowed identification of the very beginnings of the emergence of gestures, particularly those emerging before pointing gestures. Furthermore, new and systematic ways of conceptualising the behavioural coding of these gestures. The coding schemes were multi-component, viewing gestures as combinations of multiple features that are produced in a coherent, organised behavioural sequence. While we did not observe all participants produce a conventional gesture, we did catch the very beginnings of the emergence of incipient behaviours; those that consistently precede the emergence of the conventional gestural forms, and are plausibly part of their developmental history. We found that incipient forms of the four gesture types investigated began to appear from 7 months onwards (depending on the gesture type).

This study has also documented and described *incipient* gestures for these gestures and pointing gestures; behaviours that involve components of a conventional gesture but which are missing key components. Exploring a range of examples from observations and maternal reports, a case was made for why these various behaviours should be considered relevant steps along the developmental pathway to conventional communicative gestures. Behavioural features have been identified that indicate that young infants (as young as 7 months) have some burgeoning capacity to engage in communicative gestures, or at least intend to communicate gesturally, even if they are not yet capable of conventional communicative gestures. On this view, conventional communicative gestures are a product of a series of gradual cognitive and motoric developments that take place in the context of repeated social engagements (Liszkowski & Rüther, 2021).

Future work can explore what capacity and understanding infants might possess at different stages of gesture development, and, as some researchers have already begun to do with the development of giving (Bruner, 1977, 1983; Carpendale et al., 2021; de Barbaro et al., 2013; Hay & Murray, 1982; Xu et al., 2016), can also more closely examine changes at the level of the caregiver-infant dyad. By examining the capacities of infants (at the level of the infant), as well as developments in patterns of shared activity at the level of the dyad, it will be possible to articulate the key cognitive, motor and interactive processes that contribute to the emergence of infants' earliest gestures (Matthews et al., 2012).

This study used discrete categories (scores of "0", "1" and "2") that rendered these behaviours amenable to analysis, in practice these behaviours are graded phenomena. Indeed, even amongst instances of scores of "2", there were some that were clearer examples than others. Furthermore, an infant receiving a score of "2" did not mean that there was no further development to occur. For example, humans can use showing gestures in sophisticated ways. An adult can produce a slight, subtle show when being discreet, or can show particular facets of a complex object (e.g. showing the wheels on a toy car, not just the car). Thus, there is still further scope to explore how infants' capacity to show objects is refined as they become more skilful in this gesture.

Finally, future work can assess caregiver understanding of incipient gestures by exploring in depth how caregivers respond to possible or partial gestures by infants in live interactions. As the examples in section 4.3 show, caregivers are willing to entertain a range of non-conventional acts as potential communicative gestures. We have suggested that incipient gestures may serve as interactive "triggers" for caregiver responses, and examining caregivers' verbal and behavioural responses to incipient gestures will provide further evidence about whether and, if so, how caregivers respond to incipient gestures, and the role these responses may play in the origins of communicative gestures.

4.5 Conclusion

To summarise, there is still much to be understood about the development of communicative gestures, especially the developmental processes that precede the emergence of conventional communicative gestures. Whilst progress has been made in understanding the origins of pointing gestures (Brune & Woodward, 2007; Butterworth, 2003; Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018; Liszkowski & Rüther, 2021; Masataka, 2003; Matthews et al., 2012; O'Madagain et al., 2019), it is critical to our understanding of joint attention and communication that we understand the origins of other key gestures, especially those that are some of the earliest means by which infants communicate with others.

CHAPTER 5

ASSESSING FURTHER RELEVANT SOCIAL, COGNITIVE AND PHYSICAL DEVELOPMENTS BETWEEN 6 AND 10 MONTHS

This chapter reports on the social, cognitive and gross motor abilities that were examined in addition to joint attention looks and communicative gestures. They fall into three categories. First are social developments, which include imitation and attention following. Second are cognitive developments, which include means-ends understanding and object permanence understanding. Third are gross motor developments, which include independent sitting and self-locomotion. As will be explained in each section, each of these developments are relevant to the overall project of understanding the very beginnings of the development of joint attention and communication in the latter half of infants' first year.

Because of the range of different skills covered in this chapter, the different developments are covered one after the other, with their own introduction, method, results and discussion sections. Because of the particular focus on social developments, these abilities are discussed in greater depth.

5.1 Social Developments

5.1.1 Imitation

Here, we define imitation broadly as the intentional reproduction of the form of another's action, whether that involves the body alone or an object of some kind (Whiten et al., 2009). Whilst debates persist regarding the possibility that neonates can imitate simple bodily actions (Meltzoff & Moore, 1977; Meltzoff et al., 2018) or whether this ability emerges only later in development (Davis et al., 2021; Jones, 2009; Oostenbroek et al., 2016), there is no question that imitation plays a vital role in humans' ability to learn from (Legare

& Nielsen, 2015; Whiten et al., 2009) and to connect with (Meltzoff, 2005; Over & Carpenter, 2013) other persons.

Imitation is particularly salient to the current study for its potential role in the acquisition of communicative abilities. There is some evidence that imitation is involved in the acquisition of communicative gestures and language (Tomasello, 1999). Indeed, some researchers have suggested that imitation ought to be viewed as a form of communication. Užgiris (1984) argued that imitation is a form of communication, which conveys "sharing of a feeling, understanding or goal" (p.25). This view is shared by Carpenter and Liebal (2011), who argued that the sharing of mental states always requires communication, and thus imitation ought to be viewed as a communicative ability. If these claims are correct, we would expect imitation to be developmentally associated with joint attention looks and communicative gestures.

There is some previous empirical work that has examined relations between imitation and communicative skills such as joint attention, gestures and attention following, with mixed results. Bates and colleagues (1979) found that imitation (combining vocal and action imitation) predicted later production of communicative gestures and language. Carpenter and colleagues (1998) found significant correlations between the age of emergence (AoE) of imitation and point following (though not gaze following, or combined gaze and point following scores), as well as between imitation and declarative pointing (though not other declaratives such as showing and giving). Striano and colleagues (2009) found relations between the AoE of imitation and the AoEs of gaze following (though not point following) and co-ordinated visual attention. In contrast, Slaughter and McConnell (2003) found no relations between imitation and social referencing or gaze following. Thus, whilst there are some indications of possible relations, there is no clear pattern from previous work.

A key issue in understanding how imitation relates to other early abilities is that there remain disagreements regarding when exactly imitation emerges in development (here, avoiding debates over neonatal imitation). It is also not clear if there are differences between dyadic imitation (involving bodily actions only) and triadic imitation (involving actions on objects). Previous studies that have examined dyadic imitation have had mixed results, with Jones (2007) finding that some forms of dyadic imitation (e.g. tapping a surface, clapping hands, waving bye) can be observed between 6 and 10 months (Jones, 2007), but with infants not consistently doing so until 12 months. Carpenter and colleagues (1998), using actions like tapping a hand or head on a surface, only identified dyadic imitation after 9 months. It is important to note that while Jones' study had parents model the target actions, Carpenter and colleagues' had actions modelled by an experimenter, which may account for these differences.

Whilst some have claimed infants as young as 6 months can triadically imitate, others have argued it emerges after 9 months. There is some evidence that infants as young as 6 months can copy very simple actions, such as pressing a button, removing a glove from a puppet, and waving an object (Barr et al., 1996; Collie & Hayne, 1999; Herbert et al., 2006). However, the simplicity of the assessed actions makes it unclear as to whether infants were actually imitating actions, whilst the number of infants at these ages actually producing these actions was typically very low. For example, only 4 out of 12 (33%) produced the simplest of the three possible target actions (removing a puppet's glove) in the study of Barr and colleagues (1996).

Other studies have found imitation emerges only after 9 months. Carpenter and colleagues (1998), following infants monthly from 9 to 15 months, found that infants' ability to imitate triadically emerged predominantly after 9 months, with the majority of infants becoming capable of triadic imitation by 12 to 15 months. Similarly, Striano and colleagues

(2009), following infants weekly from 7 to 10 months, found no infants that engaged in triadic imitation until after 9 months, whilst Slaughter and McConnell (2003), infants aged between 8 and 14 months, identified that infants that imitated novel actions were, on average, older than 11 months. However, Meltzoff reported that, in a sample of 9-month-old infants, half imitated 2 or 3 of the 3 actions (all triadic) on which they were assessed, which may suggest that at least some of these infants were capable of triadic imitation before they were 9 months old.

Whilst cross-cultural work on infant imitation is limited, those studies that do exist have found similar patterns of emergence when comparing culturally and socioeconomically diverse populations. Whilst some of this research focused on the behaviour of toddlers and older children (Callaghan et al., 2011; Eckerman & Whitehead, 1999; Nielsen & Tomaselli, 2010), there is evidence at younger ages. In the study of Callaghan and colleagues (2011), parents from the different assessed cultures (Canada, India and Peru) started to report imitation when their infants were around 10 months of age. Graf and colleagues (2014), building on previous work by Goertz and colleagues (2010) using experimental methods, focused on 6- and 9- month olds. They compared German and Nso (a people group from northern Cameroon) infants in tests of delayed imitation. In these studies, the German sample were from a Western, industrialised population with high levels of formal education in an urban environment, whereas the Nso sample were from a non-Western, subsistence-based population with low levels of formal education in a rural environment. Children from these cultures grow up with different experiences with objects (Keller et al., 2005). Despite these differences, both populations showed similar patterns of an increase in target behaviours after observing a model produce these behaviours. Thus, from the limited cross-cultural data that exists, it appears that infants tend to start to imitate between 6 and 10 months in different cultural contexts.

It may well be the case that studies identifying imitation at 6 months may be identifying an emerging or fragile capacity to imitate (Graf et al., 2014), which is only established later in development, at around 9 months. In this vein, some previous work has also sought to understand the development of imitation by investigating behaviours that might precede the emergence of imitation. Focusing on the emergence of imitation, Kaye and Marcus (1981) sought to identify precursor behaviours on the developmental route towards mature imitation, examining bodily movements, actions on objects and vocalisations. Following infants monthly from 6 to 12 months on the same sets of actions, they suggested that infants "worked up to" (p. 258) target actions over time, producing components of the action without the full sequence. For example, when the target action was opening and closing one's mouth five times, infants first opened and closed their mouth once. When the target action was touching one's ear with an index finger, infants first touched their face. Whilst this study was limited by a small (n = 9) sample size, it does provide some indication that there may be behavioural indicators of an incipient understanding of imitation that emerges prior to a clear understanding.

This survey of the previous literature suggests that infants across different cultures start to engage in simple forms of imitation some time between 6 and 10 months. The strongest available evidence suggests that infants become capable of imitation at around 9 months of age, with potential for a "fragile" or emerging capacity prior to this emergence (Graf et al., 2014; Kaye & Marcus, 1981). Thus, the age of range of this study is well-placed for assessing the very beginnings of imitation, as well as exploring potential precursor behaviours (scores of "1").

This study also seeks to improve on previous studies that have assessed early imitation and its relation to other communicative abilities. Arguably, methodological factors have limited previous studies in different ways. Slaughter and McConnell (2003) did not use a longitudinal design, meaning the actual AoE of imitation was not clear. Bates and colleagues (1979) had no assessments of object-based imitation, whilst Striano and colleagues (2009) used only object-based imitation, and the same task at every session. Carpenter and colleagues avoided these issues, but started when infants were 9 months old, which has been suggested to be after some infants are capable of imitation.

In order to overcome these methodological concerns, the present study combined a number of important features that allowed it to provide a robust assessment of the emergence of imitation. First, it focused both on bodily (dyadic) imitation and object-based (triadic) imitation, with actions designed to be simple enough to be within the capabilities of infants, but not so simple that they could be performed by infants' spontaneous or exploratory actions (Carpenter et al., 1998). Second, it started at a younger age (6 months) and used more regular sampling intervals than many previous studies. Next, a novel task was used at each session, minimising the possibility of learning effects from session to session. Finally, both clear instances of imitation and partial or attempted instances were examined to try and identify behaviours that were part of the developmental pathway towards imitation.

5.1.1.1 Method

Two sets of tasks were used to assess infants' capacity to imitate: dyadic imitation (of bodily actions) and triadic imitation (of actions on objects). Different types of dyadic and triadic imitation task were used at each session, and the orders in which infants received the tasks across the different sessions were randomised.

Procedure. All tasks began with E getting the infant's attention and saying, "Look [infant's name], watch this!" E ensured that the infant's attention was on the display of the action throughout, saying "Look!" or "Keeping watching!" if the infant got distracted. The action was performed three times. After doing so, E said "Now you try it!" After 5 seconds, if the infant had not responded, E said “Can you try that [infant’s name]?” or “Can you try it?” If the infants still had not responded after a further 5 seconds, E would repeat this phrase again. After another 5 seconds, if the infants still had not responded, the task would end. If the child successfully completed the target action, the task would end, with E speaking positively to the infant regardless of their behaviour (e.g. “That’s great!” or “Very good!”). The actions are as follows.

Dyadic Imitation. This task investigated infants’ ability to imitate an action performed with the body. The actions are as follows.

Clap. The table was placed to the side. E brought his hands together three times per demonstration.

Hands on Head. The table was placed to the side. E raised his hands and placed his palms on the top of his head. As he did so, he made a “Weee!” noise in order to maintain the infant’s interest in the movement.

Hands to Cheeks. The table was placed to the side. E raises his hands and placed his palms on his cheeks. As he did so, he made a “Weee!” noise in order to maintain the infant’s interest in the movement.

Hands on Table. The table was placed between E and the child. E raised his hands and placed his palms on the table in front of him. He then held them there for 2 seconds. As he moved his hands, he made a “Weee!” noise in order to maintain the infant’s interest in the movement.

Open and Close Hands. The table was placed to the side. E raised both hands so that both his palms were facing towards the infants, at the infants’ eye level. He then closed and opened both hands simultaneously, three times per demonstration.

Triadic Imitation. Different stimuli were used at each session, making 5 in total. The order of the stimuli for each infant was randomised. Three of the stimuli (hinge, collapsible cup, cup) were attached to a weighted board. This board was too heavy for the infants to lift, and the stimuli were attached using a strong Velcro strip, which was weak enough for E to attach and detach objects easily but strong enough that it was challenging for the infants to move the objects.

Close Hinge. This task made use of a hinge made out of two pieces of thick cardboard secured to a metal hinge (length when unfolded 26cm, width 7cm). The two halves of the hinge were covered in bright coloured contact paper; one half red, the other orange. The bottom half of the hinge was attached to the weighted board, and placed on the table in front of the infant with the hinge open to an angle of approximately 135˚. E then performed the action, taking the top part of the hinge with one hand and closing it. As he did so, he made a "Weee!" noise in order to maintain the infant's interest in the action. Each time the action was demonstrated, E returned the hinge to an angle of 135˚.

Collapse Cup. This task used a cup (height 7.5cm, diameter 6cm) comprised of rings of increasing size that could be pulled up to lock into a cup shape. A round piece of cardboard was attached to the largest (top) ring, and this was covered in red contact paper. This was to provide a solid, salient surface to be pressed. E placed the apparatus on the table in front of the infant. He pulled the rings up into the cup shape. E then performed the action, moving his hand down towards the cup in a wide arc whilst making a "Weee!" noise to make the action salient: He brought his hand into contact with the cardboard at the top of the cup, pressing down and collapsing the rings. Each time the action was demonstrated, E then returned the rings to the cup position.

Place Toy in Cup. This task used a hard plastic cup (height 4.5cm, diameter 7cm), and the session's small animal toy, a horse. He then sought the infant's attention to the small toy. When the infant's attention was on the toy, E moved it in an arcing motion into the air above the cup, and then brought it down into the cup and released it. While doing the motion, E made a "Weee!" noise to make the toy salient.

Remove Pipe End. This task used a pipe (length 21.5cm, diameter 3cm). The main body of the pipe was blue, with two identical white tips, one of the which was removable. The action was to hold the pipe horizontally in front of himself, before removing the end of the pipe, making a "Weee!" noise whilst doing so. Each time after performing the action, E re-attached the end piece to the pipe. After completing these actions, E gave the pipe to the infant, holding it horizontally as he did so.

Rotate Pipe. This task used the pipe previously described. For this task, the action performed was to rotate the pipe 180˚. E always started the action holding the pipe directly in front of him in his right hand, around 10 cm above the table, gripping the centre of the pipe with his palm facing upwards. For the action itself, E rotated his wrist anticlockwise until his palm faced downwards. As he did so, he made a "Weee!" noise to make the action salient. Each time after performing the action, E returned it to the initial, palm-upwards position. Again, E presented the pipe to infants horizontally, with his palm facing down.

Behavioural Coding. Table 5.1 displays the three-level coding scheme for imitation.

Table 5.1

Behavioural Coding Scheme for Imitation

Score	Description
2	The infant intentionally successfully completed the target action, and did so by imitating E. For triadic imitation, the infant's gaze had to be on the target object during the performance of the action.
1	The infant attempted the target action, but was unsuccessful, or the infant performed an action that approximates the target action, but the action was not fully performed. In either case, the action had to be conducted in response to E's performance of that action.
0	The infant made no attempt to produce the target action, or only coincidentally completed the target behaviour (i.e., not by imitating E).

Note. The full version of the coding scheme, with details of the scoring for each stimulus, can be found in Appendix 5A, section 5A1.

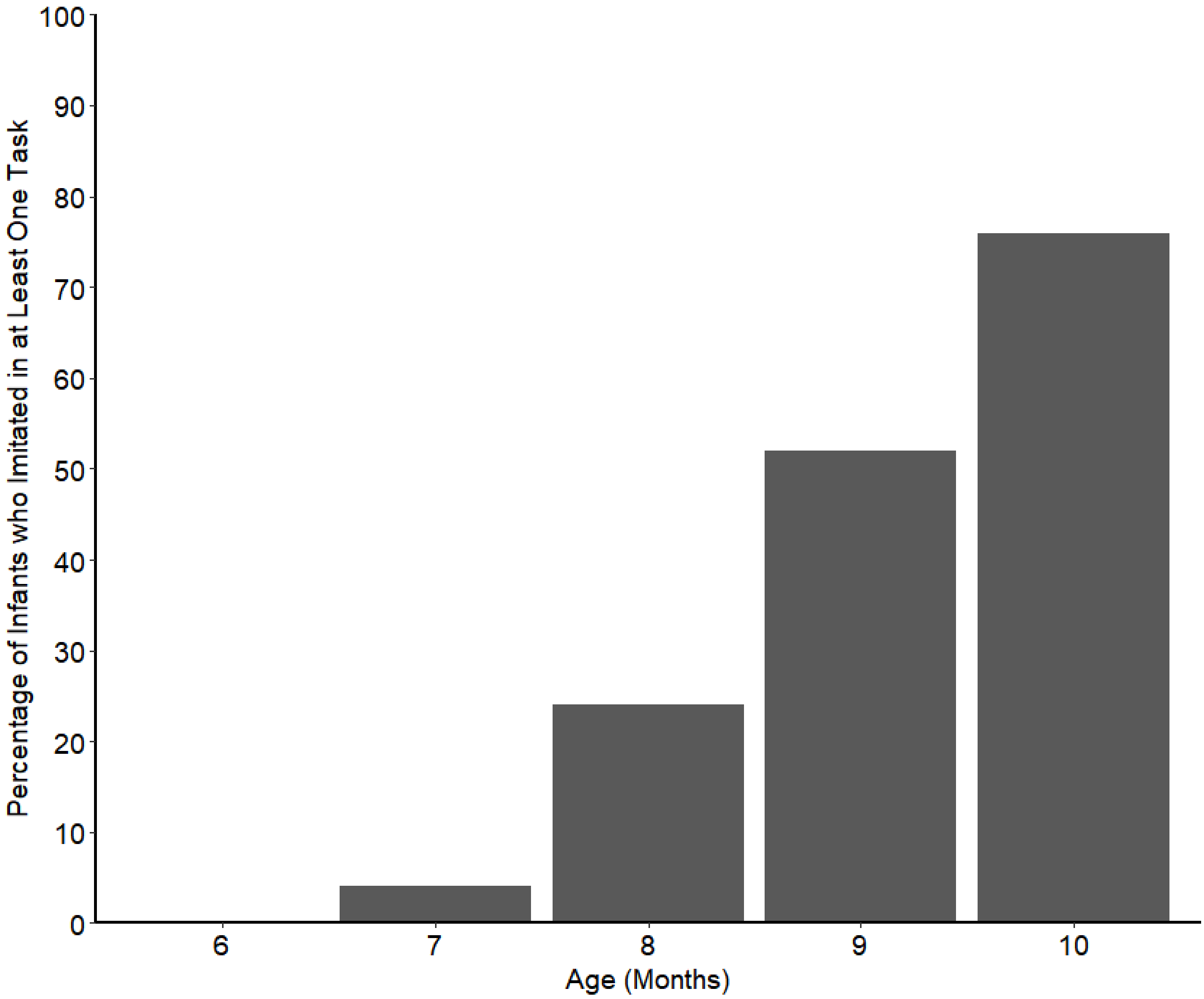
For the dyadic imitation tasks, because some of the target actions were actions that the infants might have performed without imitating E (for example, spontaneous clapping or spontaneous placement of hands on the table top), care was taken to assess whether the responses were genuinely imitative. If the infant had performed the action immediately prior to E's modelling of that action (without E having noticed at the time), then the behaviour was discounted. For the triadic imitation tasks, since some of the target actions could be performed accidentally, coders were asked to judge whether the action was intentional or accidental in cases in which the required action was completed. The requirement to visually attend to the target object was introduced to contribute to this coding requirement. If it was not clear whether the act was intentional or accidental, coders took a conservative approach and gave a lower score, in line with the overall approach. For each of the tasks, infants were scored as producing the target action if they performed the action using one or two hands, even if the demonstration involved only one or both hands.

5.1.1.2 Results

Figure 5.1 displays the cumulative totals of infants who received a score of “2” for either kind of imitation (i.e. dyadic and/or triadic imitation).

Figure 5.1

Cumulative Totals of Infants who Received Scores of "2" for Dyadic and/or Triadic Imitation for each Month



The earliest instance of imitation was at 7 months, when one infant engaged in dyadic imitation, and by 10 months the majority of infants (19 out of 25, 76%) had imitated in at least one task. Of these 19, 5 infants (26%) received a score of "2" in both tasks.

A GLMM was specified in order to examine whether a significant increase in imitation occurred between any consecutive months. Age was entered as a categorical fixed effect, and participant as a random effect. The dependent variable was a binary outcome, imitation production (0 for no imitation in either task, 1 for imitation in either task (score of "2")). The model used a binomial error structure and logit link function. The table of model coefficients can be found in Appendix 5B, Table 5B1.[1] A Tukey's HSD post hoc test on age revealed no significant difference in imitation production between any two consecutive months.

Figure 5.2 displays the imitation scores at each month, separately for each type of imitation, using the three-level coding scheme.

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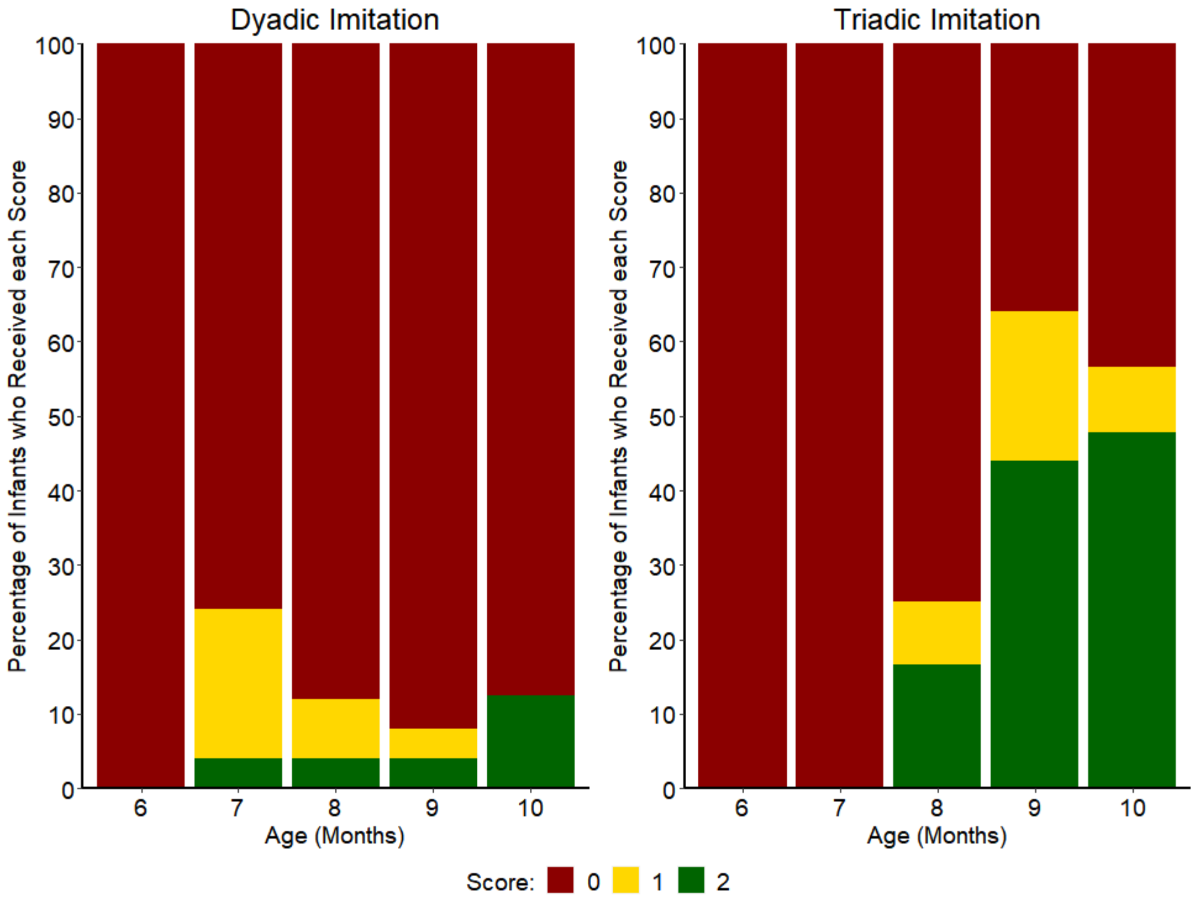
[1] All further GLMMs followed the same structure, with a binary dependent variable (0 = target behaviour not produced, 1 = target behaviour produced). To avoid needless repetition, details of the model structure are not repeated for each subsequent analysis.z

Figure 5.2

Percentage of Infants who Received Scores of "0", "1" or "2" for Dyadic and Triadic Imitation at Each Month



Whilst the first recorded instance of dyadic imitation took place at 7 months, few infants engaged in dyadic imitation overall, with only 6 out of 25 (24%) of infants imitating dyadically over the course of the study. None of these infants engaged in dyadic imitation at more than one session. Only 8 out of 25 (32%) of infants received a score of "1", and of the 6 infants who received a score of "2", in only 1 (17%) case did a score of "1" precede a score of "2". This proportion was not different from chance ($p = 0.22$, 95% CI [0.00, 0.64]), suggesting that scores of "2" were consistently not preceded by scores of "1", and thus that the scores of "1" that we identified ought not necessarily be considered precursor or incipient forms of dyadic imitation. However, given the generally low numbers of "2" scores, it is difficult to make any strong claims in either direction. No model was specified to examine sudden increases in dyadic imitation due to the low number of responses. Finally, infants were not especially successful in any single task. There were 2 instances of imitation (i.e. scores of “2”) in Clap and Hands on Head, 1 in Open and Close Hands and Hands to Cheeks, and 0 in Hands on Table.

The first infants to engage in triadic imitation started from 8 months of age (4 out of 25; 16%), and by 10 months, 18 out of 25 (72%) infants had engaged in triadic imitation. Seven out of 25 (28%) infants received a score of “1”. Of the 18 infants who received a score of “2”, in only 3 (17%) cases did infants received a score of “1” before a score of “2”. This ordering was significantly different from chance (p = 0.008, 95% CI [0.04, 0.41]), indicating that scores of “2” were consistently not preceded by scores of “1”, and thus that the scores of “1” that we identified ought not necessarily be considered precursor or incipient forms of triadic imitation. A GLMM was specified in order to examine whether a significant increase in triadic imitation occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B2. A Tukey’s HSD post hoc test on age revealed no significant difference in triadic imitation production between any two consecutive months. Finally, there were marked differences in the tasks in which infants imitated (i.e. received a score of “2”). Fifteen infants imitated in Collapse Cup, 6 in Close Hinge, 4 in Rotate Pipe, 1 in Remove Pipe End and 0 in Place Toy in Cup.

5.1.1.3 Discussion

Overall, the result show that the majority of infants were capable of some form of imitation by 10 months. The majority of these infants were engaging in triadic imitation rather than dyadic imitation, although it is worth noting that at any given month, fewer than half of infants imitated the triadic imitation task. These findings are broadly in line with previous findings that report imitation emerging at around 9 months (Carpenter et al., 1998; Slaughter & McConnell, 2003; Striano et al., 2009). Performance in the dyadic imitation tasks was sporadic, with overall low rates of success despite the earliest instance taking place at 7 months. Whilst Jones (2007) reported sporadic production of bodily actions before 10 months, dyadic imitation was much more inconsistent in the present study. One possible source of difference is the fact that it was E modelling the actions, not a caregiver.

Why were there such differences in performance between the dyadic and triadic tasks? A possible explanation is the interplay between learning and social goals (Over & Carpenter, 2013). Imitation can involve a motivation to connect socially with another, to learn new information, or some combination of the two. Dyadic imitation arguably does not provide the novel learning opportunities that triadic imitation offers, and thus may primarily serve to promote interpersonal affiliation (Meltzoff, 2005). Infants may not have been motivated to engage in dyadic imitation with a relatively unfamiliar adult. Whilst triadic imitation also facilitates interpersonal affiliation, it has the added benefit of learning something about a novel stimulus, providing further motivation to engage in that act. Finally, it may simply have been that the triadic imitation situations, by virtue of involving novel stimuli with which infants could interact, were generally more interesting, meaning the infants were more attentive and likely to be engaged in the task (even though it was ensured that infants had established eye-contact prior to the modelled bodily action, and the actions were only produced when the infant was visually attending to E).

As the introduction to this section argued, it is imitation of novel actions that provides the strongest evidence for an understanding of imitation. If not, it is difficult to be sure that an infant has not simply learned how to act on a familiar object or perform a familiar action when using a longitudinal approach (Carpenter et al., 1998). A subsequent limitation of this study was that, like a number of previous studies (Carpenter et al., 1998; Slaughter &

McConnell, 2003; Striano et al., 2009), it assumed that a general imitative competence that underpins all tasks could be detected. However, in triadic imitation, there were more instances of imitation in Collapse Cup than in the rest of the tasks combined (15 against 11). This may partly have been to chance- the randomisation of task orderings happened to occur in such a way that a large proportion of the infants received Collapse Cup at 9 or 10 months (17 out of 25)- but suggests that this task was more within infants' capacities than the others. The only comparable task was Close Hinge, with 6 successes (with only 7 infants allocated this task at 9 or 10 months). Whilst a pseudo-randomisation approach could have been adopted to avoid uneven allocation of tasks, these results suggest that the type of task was more relevant to infant performance than the design assumed.

In particular, it would seem that the motoric requirements played a more significant role than predicted. The tasks were designed to be broadly similar in motor difficulty, but in practice certain actions (removing the pipe end, placing a toy in a cup) proved to be especially challenging for some infants. This issue also pertains to the ordering of "1" and "2" scores. In both types of imitation task, infants did not consistently receive scores of "1" before scores of "2". However, given the evidence that triadic imitation performance was strongly linked to task type, it may be incorrect to assume that a "1" in one task has much relevance for a "2" in another, despite both involving imitation. Overall, these findings could be argued to be in accord with Jones' (2007) argument that "imitation is not a single competency that appears all at once" (p. 598). However, for the purposes of this study, it is still relevant to be able to record the first point at which infants show a capacity to imitate, and how this emerging capacity might relate to other developing skills.

It is also relevant to note a further finding that pertains to the origins of imitation. Some infants were able to imitate (or, arguably, emulate; Huang et al., 2002) another's action by providing motoric workarounds that enabled them to reproduce a very similar action, but in a manner that was within the infants' motor capacities. In the dyadic imitation task "Hands on Head", two of the infants, one at 7 months and another at 8 months (as well as a third infant, aged 8 months, during piloting) devised an ingenious solution to overcome their sensorimotor limitations and successfully perform the action of raising their hands to their head. First, the infants locked their fingers together, creating tension between both arms. Then, they would raise both arms towards the top of their head, keeping their hands and fingers locked together, with the hands ending up at the top of their forehead. By doing so, the infants were able to approximate the target action, clearly demonstrating the intent to replicate the act. The locking of the fingers together seemed to be an important part of allowing the infants to complete the act of raising, as this was performed prior to the raising each time (rather than first bringing the hands together at forehead height). These acts are pictured in Figure 5.3.

What is interesting about this sequence is that it differed from the action performed by E, who raised each arm separately and placed the palms of his hands flat on the top of his head. The infants observed this action and devised an approximated means of performing it that captured the key properties of the act while being within their own sensorimotor capacities. This solution demonstrates the infants' intelligent and surprisingly sophisticated grasp of their own sensorimotor capacities, and the employment of these capacities to imitate (or possibly emulate) another's act. Though rare, this kind of behaviour is interesting and warrants further exploration. For example, it may be possible to elicit this action more consistently by asking caregivers to model the behaviour in the home context, which may provide a more relaxed and naturally playful environment than a lab.

Figure 5.3

Infants' Reproduction of Hands on Head Action

5.1.2 Attention Following

Scaife and Bruner's (1975) seminal study investigated infants' capacity to follow another's gaze to a distant target. Since then, a range of studies have examined at what ages and in what contexts infants follow another's gaze and point direction (for reviews of gaze following see Flom, et al., 2007; Shepherd, 2010; for point following see Bertenthal et al., 2014). A capacity to detect gaze and gaze direction has been observed in neonates (Farroni et al., 2002; Farroni et al., 2004), and studies with infants between 2 and 8 months of age have found that some infants are capable of gaze and point following (Bertenthal et al., 2014; D'Entremont, 2000; D'Entremont et al., 1997; Gredebäck, et al., 2010; Striano & Stahl, 2005). However, these studies have typically used very simple procedures with objects located very close to the agent whose attention is to be followed, often using eye-tracking of animated agents or features (eyes, hands) on a screen. Taking a more conservative definition of attention following, requiring demonstration of an understanding of a physically present agent's attention to a specific object (rather than solely the general direction of that agent's attention), this ability is typically identified between 9 and 11 months (Meltzoff & Brooks, 2007; Shepherd, 2010).

Attention following is often discussed as an important joint attention skill, sometimes referred to as responding to joint attention (RJA; Mundy & Newell, 2007). However, it has been previously highlighted that gaze and point following do not always involve joint attention (Carpenter & Liebal, 2011; Siposova & Carpenter, 2019). One can follow another's gazing or pointing without them being aware of it, and thus without there being any kind of jointness to the situation. For attention following to lead to joint attention, their needs to be some kind of mutual sharing of the object of attention. Even in cases in which attention following does play a role in establishing a joint attention situation, it does not necessarily require any kind of active initiation on the part of the infant.

An important question is thus quite how a capacity to follow attention relates to other early joint attention and communication skills, particular in the months prior to 9 months. Some previous research has suggested that there is a dissociation between RJA and the initiation of joint attention (IJA), with the skillsets drawing upon different cognitive and motivational capacities (Mundy et al., 2007; Mundy & Gomes, 1998). However, other research has found relations between attention following and communicative gestures (Carpenter et al., 1998; Salo et al., 2018), and numerous studies have linked attention following to language development (Brooks & Meltzoff, 2005; Delgado et al., 2002; Morales et al., 2000; Mundy et al., 2007; Mundy & Gomes, 1998; Salo et al., 2018).

Most of this work has focused on infants that are older than 12 months of age. It does not tell us if these relations already exist just as early joint attention and communication skills are beginning to emerge, or the order in which these skills emerge. Given these gaps in the existing literature, the present study included measures of both gaze and point following in order to provide a clear assessment of the beginnings of infants' attention following skills, and their relation to other joint attention and communication skills.

5.1.2.1 Method

Two sets of tasks were used to assess infants' capacity to follow attention: gaze following and point following.

Procedure. Two target objects (assorted fluffy animal toys) were placed on each of the two chairs located on either side of E (see Chapter 2, Figure 1). The height of the chairs was such that the target object was approximately at eye level for the infant. The objects for the first two trials were placed on the chairs early in the session, when the infant was not watching. Two different pairs of toys were used for Gaze/Point following in each session, such that the child was directed towards a different toy for each Gaze and Point Following trial. Shortly before the halfway point between task blocks, E switched the Gaze/Point Following toys again whilst distracting the infant as much as possible.

Gaze following. In these trials, E sought eye contact with the infant by saying “Hello, [infant’s name]!”. E ensured that eye contact was sustained at least until his head turned. If the infant looked away, E sought to re-establish eye contact. If the infant looked in the direction of the target object during the start of the trial, before E turned his head, E abandoned the trial and returned to the task later in the procedure. If eye contact was sustained, E said “Look, [infant’s name]!”, and turned his head towards the target object. Then, whilst looking at the object, E said “Wow, that’s cool!”, before turning back to the infant, smiling, and making eye-contact. The whole process was repeated twice, with slightly different utterances (“Cool, look at that!” and “That’s cool!”), for a total of three looks to the target object.

Point following. These trials proceeded in the same manner as Gaze following, except that, in addition, E pointed to the target object at the same time as he turning his gaze towards the target object. Points were performed across E’s body, with an extended index finger.

Coding. The coding of gaze and point following was very similar. The general form of the three-level scheme for both is presented in Table 5.3.

Table 5.3

Behavioural Coding Scheme for Attention Following

Score	Description
2	The infant looked at the target object in response to E's attention to the target object.
1	The infant looked to the same side as the target object in response to E's attention to the target object, but did not attend to the object itself.
0	The infant did not follow the attention of the experimenter at all.

Note. The full version of the coding schemes can be found in Appendix 5A, 5A3. The differences between gaze and point following are specified there.

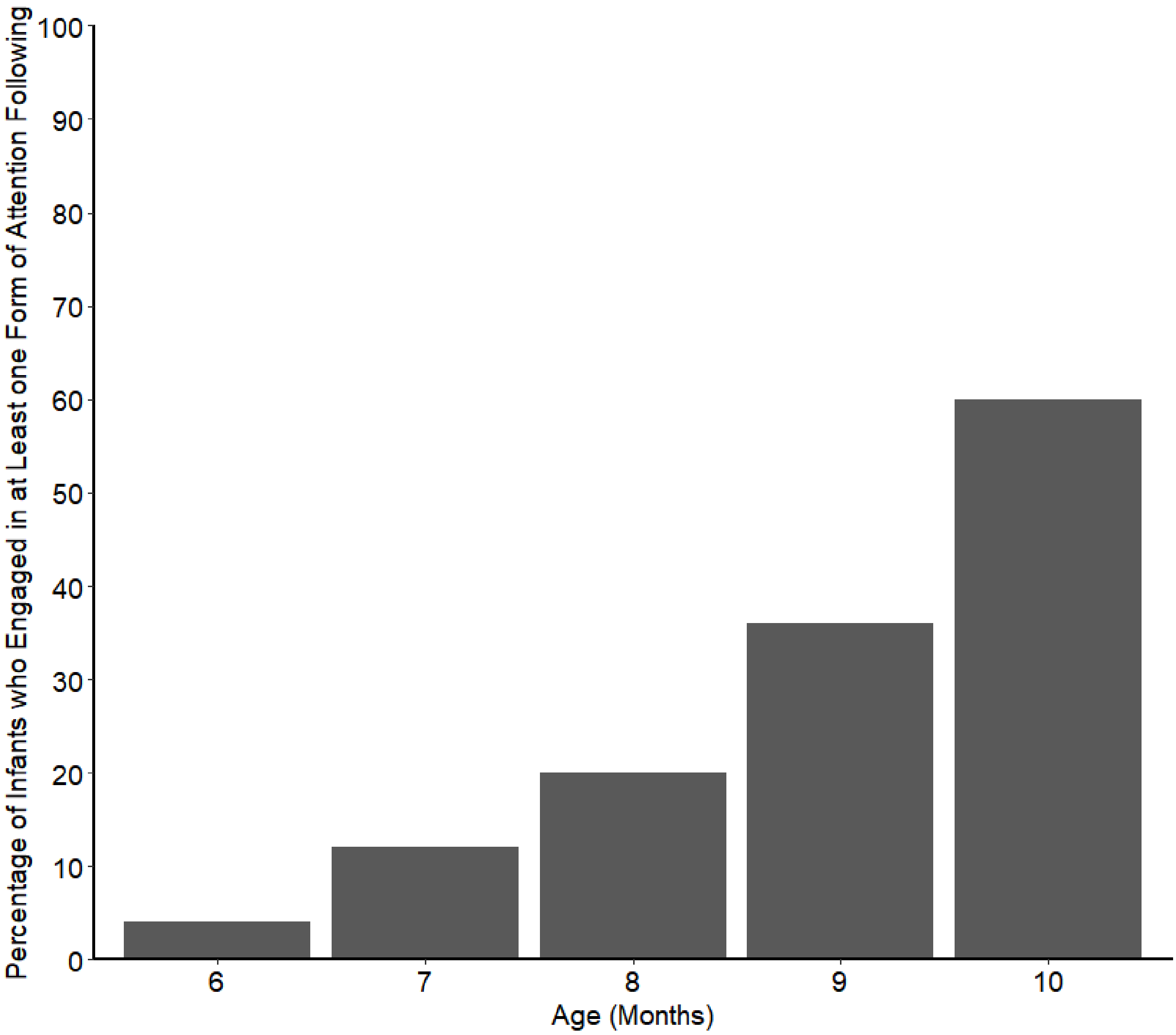
Infants were considered to have followed E's attention if they looked to E's face (gaze and point following) and/or extended finger (point following) and then looked to the target object, without looking anywhere else between these two acts. They only needed to do this at least once across the actions E performed. It did not matter how long the infant looked to E before looking at the target object. If the coder judged that the infant only coincidentally (i.e., not clearly in response to E's gaze or point) visually attended to the target object or side, a score of 0 was awarded.

5.1.2.2 Results

Figure 5.4 displays the cumulative totals of infants who were followed attention at each month, whether gaze or point following.

Figure 5.4

Cumulative Totals of Infants who Received Scores of "2" for Attention Following for each Month



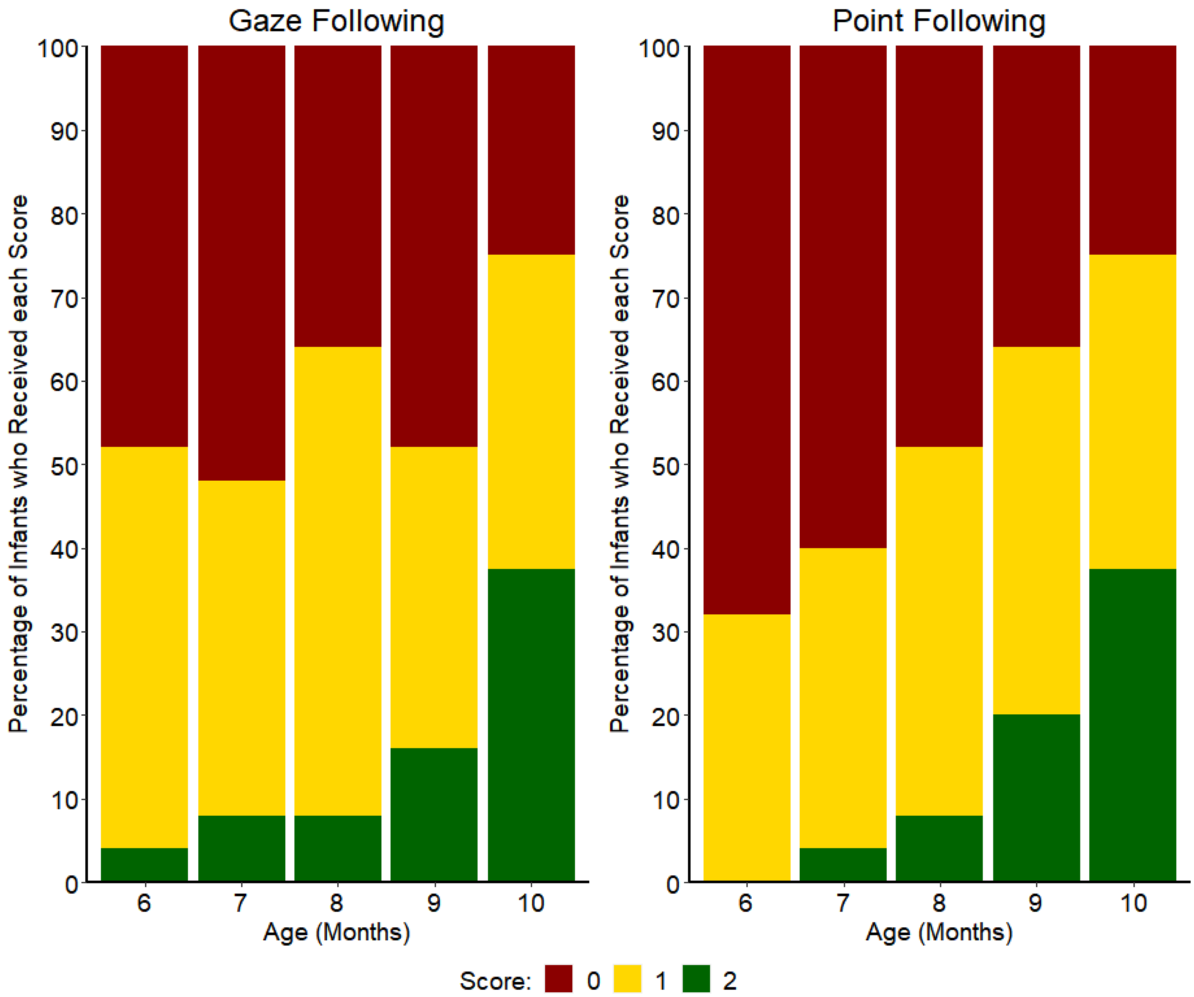
The earliest instance of attention following was at 6 months, when 1 infant (4%) engaged in gaze following. By 10 months the majority of infants (15 out of 25, 60%) had engaged in attention following in at least one task. Of these 15, 8 infants (53%) received a score of “2” in both tasks.

A GLMM was specified in order to examine whether a significant increase in attention following occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B3. A Tukey’s HSD post hoc test on age revealed no significant difference in imitation production between any two consecutive months.

Figure 5.5 shows the attention following results for the three-level coding scheme, split by task type.

Figure 5.5

Percentage of Infants who Received Scores of "0", "1" or "2" for Gaze and Point Following at Each Month



The first recorded instance of gaze following (1 infant; 4%) took place at 6 months. Twelve out of 25 (48%) of infants had engaged in gaze following by 10 months. Twenty-one out of 25 (84%) infants received a score of "1", and of the 12 infants who received a score of "2", in 9 (75%) cases did a score of "1" precede a score of "2". This proportion was not different from chance (p = 0.15, 95% CI [0.43, 0.95]), suggesting that scores of "2" were not consistently preceded by scores of "1" in the period of observation. A GLMM was specified in order to examine whether a significant increase in gaze following occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B4. A Tukey's HSD post hoc test on age revealed no significant increases in infants following gaze between any two consecutive months.

The first recorded instance of point following (1 infant; 4%) took place at 7 months. Eleven out of 25 (44%) of infants had engaged in point following by 10 months. Twenty-one out of 25 (84%) of infants received a score of "1", and of the 11 infants who received a score of "2", in 8 (73%) cases did a score of "1" precede a score of "2". This proportion was not different from chance (p = 0.23, 95% CI [0.39,0.94]), suggesting that scores of "2" were not consistently preceded by scores of "1" in the period of observation. A GLMM was specified in order to examine whether a significant increase in point following occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B5. A Tukey's HSD post hoc test on age revealed no significant difference in imitation production between any two consecutive months.

5.1.2.3 Discussion

These results are in line with previous work suggesting that infants start to be capable of attention following from 6-7 months, but with the ability being more robustly established by 10-11 months (Corkum & Moore, 1998). In addition, it was found that the ability emerged gradually across infants, with no sudden increase in the number of infants engaging in attention following of either kind, or in gaze or point following specifically. Whilst scores of "1" preceded scores of "2" in a majority of cases for both gaze and point following, the proportions of this occurrence were not different from chance in either case. It may be that this is simply due to insufficient numbers of infants displaying attention following, given previous evidence that infants follow head and gaze orientation before displaying attention following (Shepherd, 2010).

5.2 Cognitive Tasks

In this study, two cognitive tasks were used; one examining means-ends understanding and a second examining object permanence understanding. The inclusion of these tasks was primarily to provide a non-social comparison alongside the range of social abilities being assessed, in order to examine whether general cognitive maturation might explain changing performance in the social tasks. However, it has been suggested that means-ends understanding is related to infants' communicative development (Bates et al., 1979; Jones & Hong, 2001) making it especially relevant.

5.2.1 Means-ends Understanding

Means-ends behaviour involves acting on one object to affect another to achieve some desired outcome (Babik et al., 2019). It must involve goal-directed behaviour to achieve a desired outcome, rather than exploratory behaviour that coincidentally achieves an outcome (Clearfield et al., 2015). Some researchers have drawn a link between infants' understanding of means-ends relations and their understanding of communication, with both reflecting a similar structure of understanding (Bates et al., 1979; Jones & Hong, 2001). In each case, the infant achieves some goal involving a person or object using some means other than acting directly on that person or object. For example, an infant may use a tool as a means of bringing an object within their reach, or may use another person (via communicating with them) to achieve the same end. Jones and Hong (2001) found that infants' performance on means-ends tasks predicted their production of anticipatory smiles (smiling prior to or during a look from an object to an agent) to their mother, suggesting that this ability may be important to consider when seeking to understand the emergence of communication.

Previous studies have indicated that means-end understanding typically emerges between 6 to 8 months. The longitudinal studies of both Willatts (1999) and Babik and colleagues (2019) found that some infants demonstrated means-ends understanding at 6 months, with the majority doing so by 8 months. Striano and colleagues (2009) found a roughly similar pattern of emergence, though with a rapid increase in infants demonstrating means-ends understanding between 33 and 35 weeks of age, approximately 7 ½ to 8 months.

To assess infants' means-ends understanding, we examined whether infants understood that they could pull on a cloth to obtain an object that had been placed out of their reach on that cloth, instead of just reaching for the object. This approach has been used previously in studies of infants' knowledge of means-ends relations (Babik et al., 2019; Sommerville & Woodward, 2005; Willatts, 1999), and has been shown to be easier for infants than tasks that employ other movements, such as rotating a turntable rather than pulling a cloth (Babik et al., 2019). The procedure used broadly follows that of Willatts (1999), though with adjustments made given that the task was conducted alongside other tasks (limiting changes to the testing set up), with the child not on their parent's lap, and with less time within which to conduct the procedure.

5.2.1.1 Method

Procedure. The procedure for the cloth task is described in Chapter 4, section 4.1.4.1.

Behavioural Coding. A general version of the three-level coding scheme for means-ends understanding is displayed in Table 5.4.

Table 5.4

Behavioural Coding Scheme for Means-Ends Understanding

Score	Description
2	The infant successfully obtained the target object by intentionally using the cloth to bring the target object within reach and touching it.
1	The child attempted to obtain the target object by intentionally using the cloth, but was not successful.
0	The infant made no attempt to use the cloth to obtain the target object, or only accidentally obtained the target object.

Note. The full version of the coding scheme can be found in Appendix 5A, 5A4.

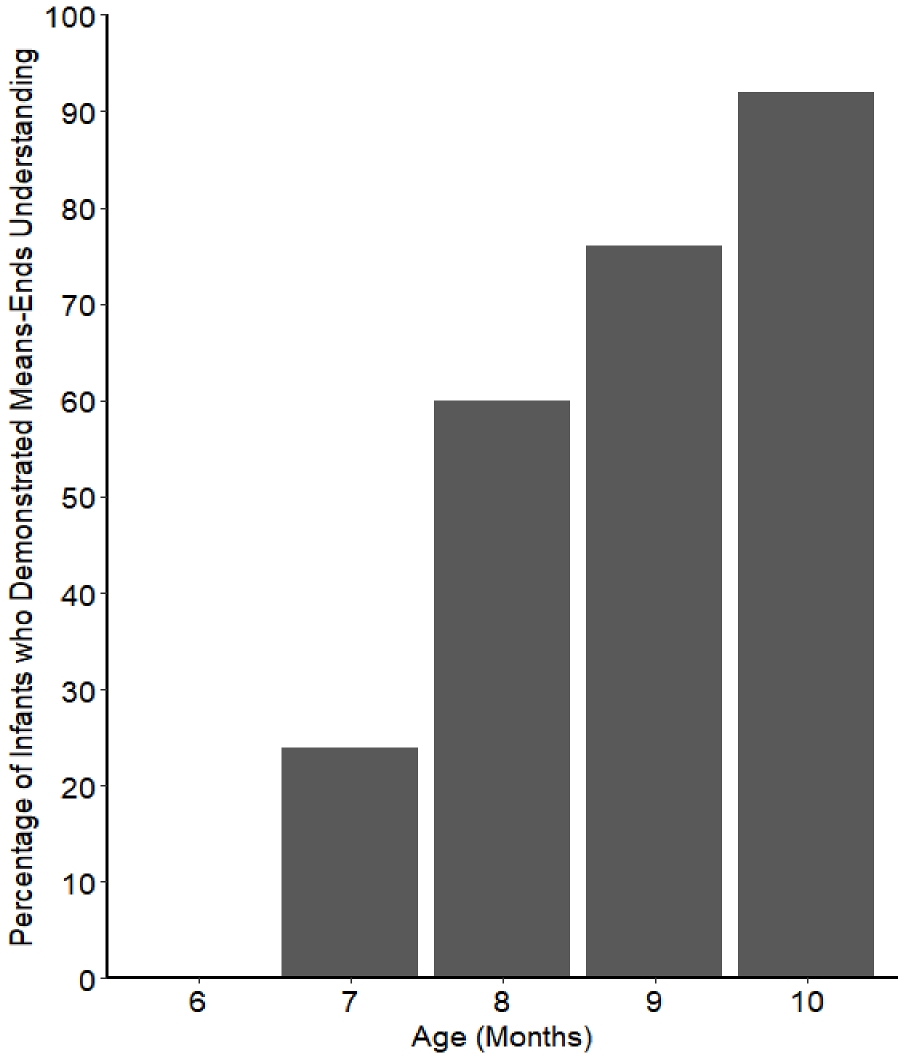
The infant was considered to have intentionally used the cloth to obtain the target object if, at some point during the process of pulling the cloth, their visual attention was on the target object. Furthermore, the infant had to come into contact with the object, otherwise it was not clear if they were interested in the toy or were solely interested in manipulating the cloth. If the infant's only attempt to obtain the toy involved the toy falling on the floor, they could only receive a score of "1".

5.2.1.2 Results

Figure 5.6 displays the cumulative totals of infants who were successful in the means-ends understanding task at each month.

Figure 5.6

Cumulative Totals of Infants who Received Scores of "2" for Means-Ends Understanding for each Month



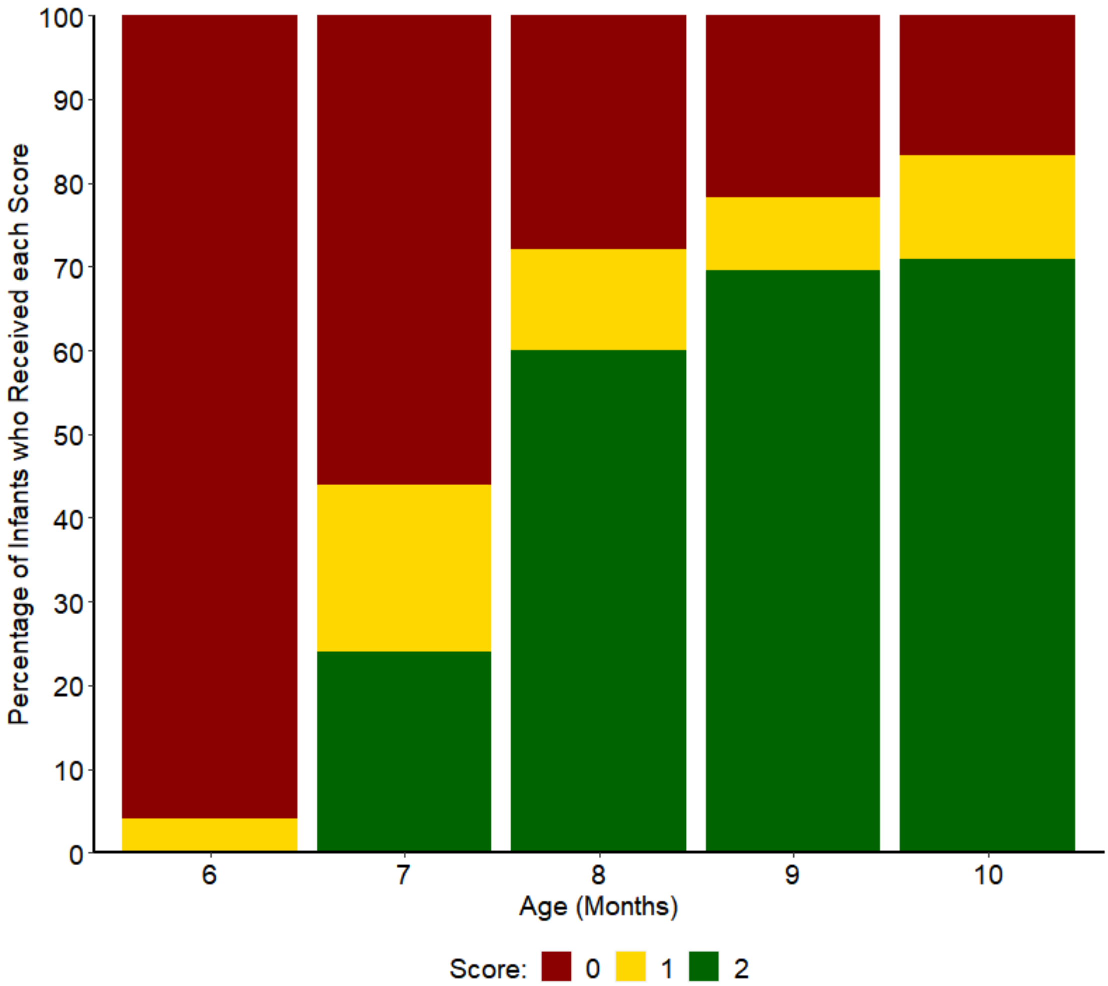
The earliest instance of means-ends understanding was at 7 months, when 6 out of 25 infants (24%) demonstrated means-ends understanding. The majority of infants (15 out of 25; 60%) had demonstrated means-ends understanding by 8 months. By 10 months, 23 out of 25 infants (92%) had demonstrated means-ends understanding.

A GLMM was specified in order to examine whether a significant increase in means-ends understanding occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B6. A Tukey's HSD post hoc test on age revealed a significant increase in infants demonstrating means-ends understanding between 7 and 8 months (z = -2.95, p = 0.03).

Figure 5.7 displays the results from the three-level coding scheme.

Figure 5.7

Percentage of Infants who Received Scores of "0", "1" or "2" for Means-Ends Understanding at Each Month



Thirteen out of 25 (52%) infants received a score of "1", and of the 23 infants who received a score of "2", in 9 (39%) cases did a score of "1" precede a score of "2". This proportion was not different from chance ($p = 0.40$, 95% CI [0.20, 0.61]), suggesting that scores of "2" were not consistently preceded by scores of "1" in the period of observation.

5.1.2.3 Discussion

The findings regarding the AoE of means-ends understanding were broadly similar to previous results (Babik et al., 2019; Striano et al., 2009; Willatts, 1999). Though no infants succeeded in the task at 6 months, infants started to pass at 7 months, with a significant increase in infants demonstrating means-ends understanding between 7 and 8 months. The pattern of emergence was very similar to that of Striano and colleagues, who found a significant increase in infants' understanding of means-ends between ages 33 and 35 weeks of age, approximately 7 ½ to 8 months of age. The slightly different pattern of emergence in comparison to other prior work may be due to minor procedural and coding differences. For example, in Willatt's (1999) study, infants were given time to familiarise themselves with the cloth before the trial, which is a step that we did not have time to perform. Additionally, infants in Willatt's study sat on their parent's lap, which would have both provided more postural support than a high chair and helped with infant mood regulation.

A final note on the means-ends task is that infants may seek a social resolution to the situation, treating it not as a means-ends task but rather as a distal request situation (Goubet et al., 2006). As previously mentioned, we coded request gestures (4.4.1.1) from the means-ends task. While some cases of "0" involved the infant showing no interest in the target object, others involved the infant making efforts to request the target object from E (2 out of 25; 8%). Whilst one could view "0" scores as "failing" the task, there are in fact different strategies available to the (communicatively capable) infant that they can employ to achieve the goal of obtaining the target object. Indeed, both kinds of responses, non-communicative and communicative, arguably demonstrate forms of means-ends understanding.

Future work could explore contextual influences on whether infants choose to obtain the object by acting on the cloth or by communicating about the object. It is plausible that there are age-related difference in strategy, and/or individual differences in sociality that influence the response strategy used. Alternatively, at some age, infants may perform a kind of cost-benefit analysis, employing social strategies if the physical effort is demanding and instrumental strategies if not. The means-ends task, whilst typically used to assess means-end understanding, may be a useful task to explore how and when infants' adopt social versus instrumental strategies.

5.2.2 Object Permanence Understanding

Infants' understanding of the physical principles of objects, such as their solidity, permanence and effects on other objects, develops significantly during the first year. Infants' exploration of their physical environment and developing "sensorimotor intelligence" was famously charted by Piaget (1952, 1954) and since his work researchers have provided detailed investigations of infants' physical understanding using a variety of methods (Baillargeon et al., 1985; Clearfield et al., 2015; Munakata et al., 1997). Research using looking-time measures has provided evidence for an implicit awareness of physical principles such as object permanence understanding and gravity from as young as 3 months (Baillargeon, 1987; Baillargeon et al., 1985; Kim & Spelke, 1992). However, it is only later in infants' first year that their understanding of these relations are expressed in action, with active measures of object permanence understanding finding that it emerges at around 8 months (Munakata et al., 1997).

A variety of methods have been employed to assess infants' grasp of object permanence understanding. We focus on infants' ability to actively demonstrate an understanding of object permanence understanding through the object search procedure, originally described by Piaget (1954) and since used in a number of experimental procedures (e.g. Moore & Meltzoff, 1999). The object permanence understanding task used broadly followed Moore and Meltzoff's (1999) "Hiding by Screen" approach (using a cloth to cover an object), which they found to be less demanding for infants than other strategies (e.g. placing an object underneath a cloth).

5.2.2.1 Methods

Procedure. E placed the table between himself and the child. E sought the infant's interest in a toy by holding a toy towards them until they attempted to grasp it. The toy car from that session's set was used (see Appendix 2A, Figure 2A2) to ensure that the object hidden was always the same size. When the infant showed interest in the toy, E placed the object in front of the infant and covered it using a 42 by 69cm cloth. E ensured that he pulled the side of the cloth closest to the infant over the object each time. E then removed his hands from the cloth and sat back, giving the infant 20 seconds to respond by manipulating the cloth or the object underneath. If the child was visibly upset, E ended the task sooner.

Behavioural Coding. Table 6 displays an overview of the three-level coding scheme for the object permanence understanding task.

Table 5.5

Behavioural Coding Scheme for Object Permanence Understanding

Score	Description
2	The infant intentionally searched for and retrieved the target object from under the cloth. The infant had to look towards the target object's location during the process of removing the cloth, and had to touch the target object after removing the cloth.
1	The infant made some attempt to obtain the target object but was unsuccessful.
0	The infant did not attempt to retrieve the target object, either expressing no interest in the cloth or only interacting with the cloth.

Note. The full version of the coding scheme can be found in Appendix 5A, 5A5.

To ensure that the infant was clearly searching for the target object (Moore & Meltzoff, 1999), we ensured that infants looked at location where the object was hidden at some point during the process of removing the cloth. If the infant removed the cloth while looking elsewhere, they could not receive a score of "2". If the infant removed the cloth but did not then interact with the target object, it was not clear that they were actually searching for that object, and thus could not receive a score of "2".

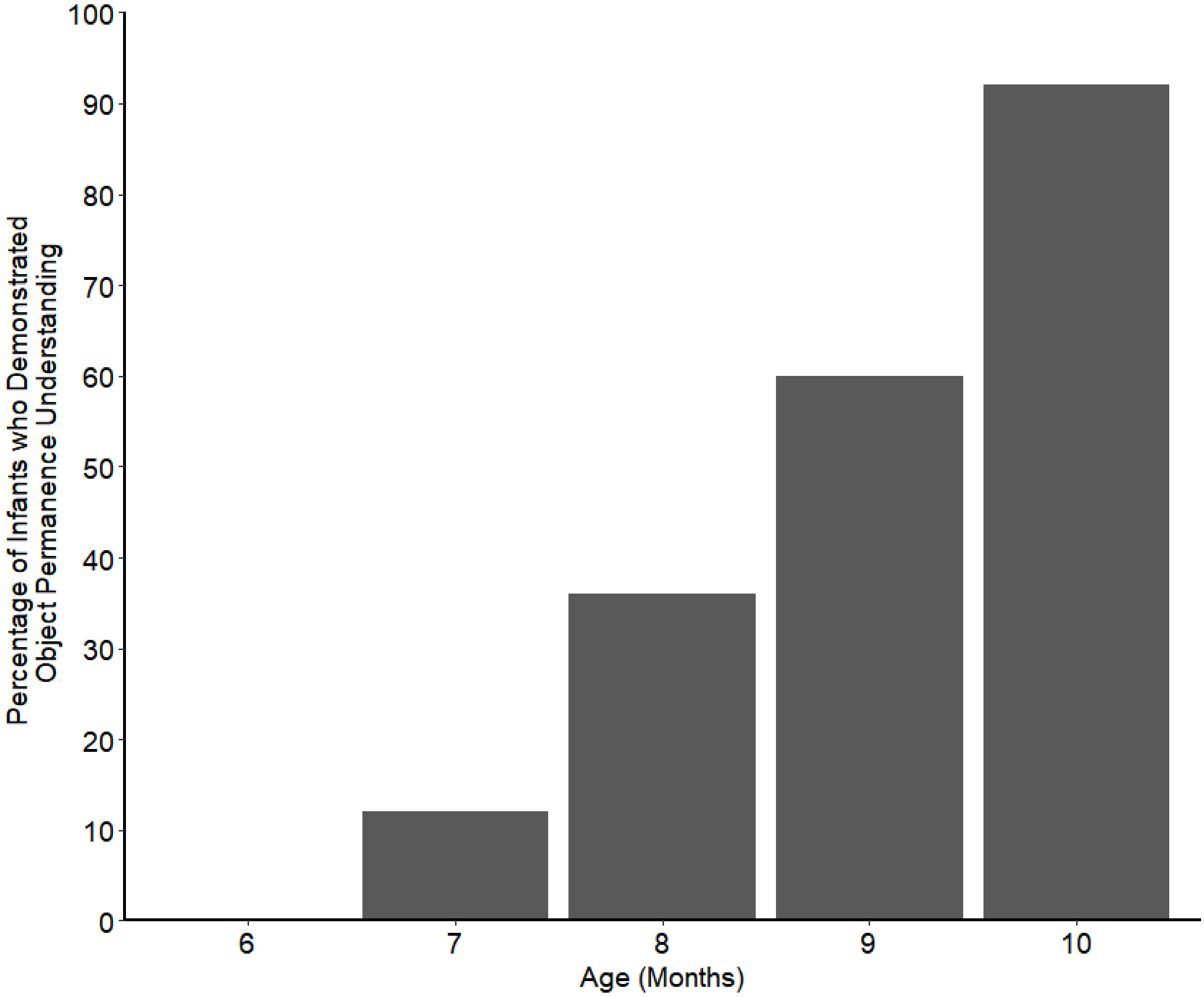
Infants could receive a score of "1" if they showed some attempt at obtaining the target object but were not successful. For example, they manipulated the object through the top of the cloth without obtaining the object, or they made an effort to search for the object but gave up their efforts before obtaining the object.

5.2.2.2 Results

Figure 5.8 displays the cumulative totals of infants who were successful in the object permanence understanding task at each month.

Figure 5.8

Cumulative Totals of Infants who Received Scores of "2" for Object Permanence Understanding for each Month



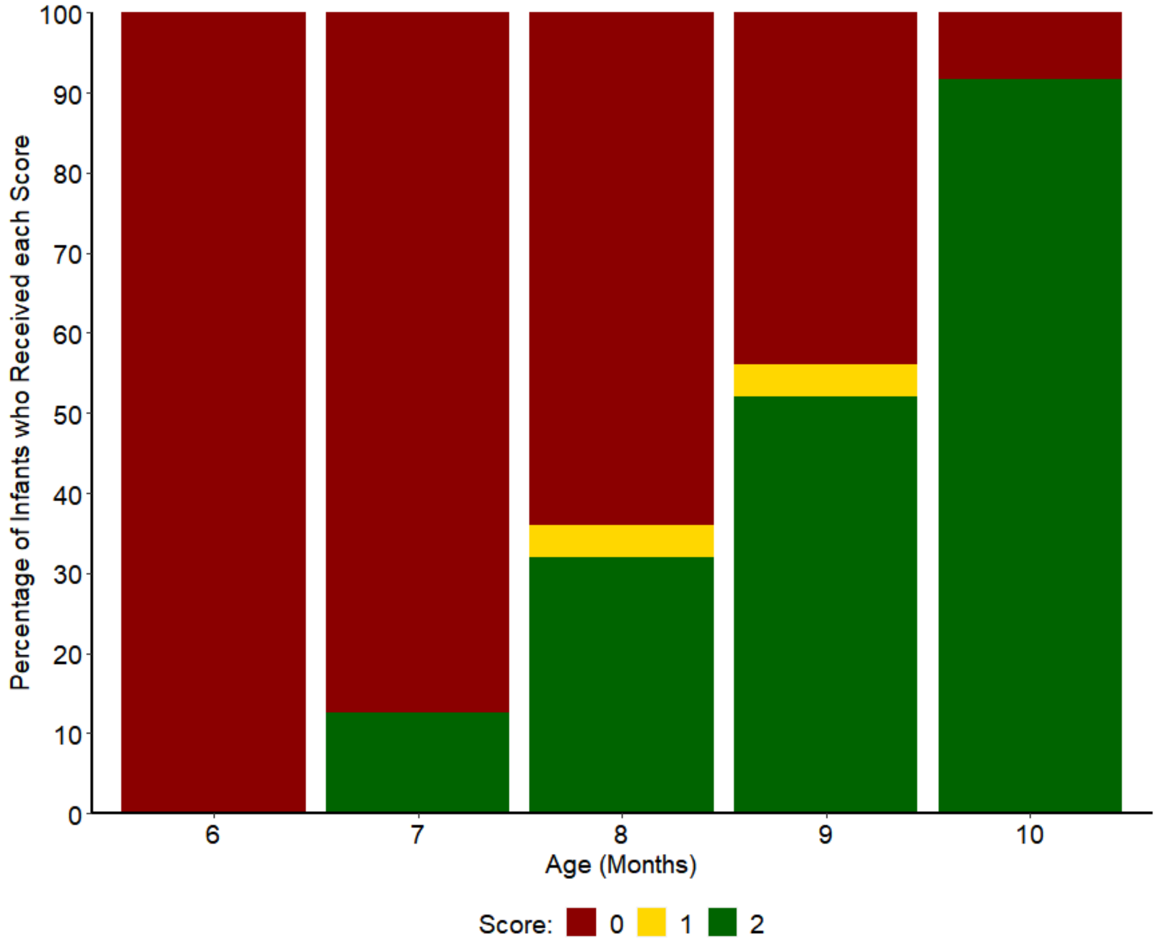
The earliest instance of object permanence understanding was at 7 months, when 3 out of 25 infants (12%) demonstrated object permanence understanding. The majority of infants (16 out of 25; 64%) had demonstrated object permanence understanding by 9 months. By 10 months, 23 out of 25 infants (92%) had demonstrated object permanence understanding.

A GLMM was specified in order to examine whether a significant increase in infants demonstrating object permanence understanding occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B7. A Tukey's HSD post hoc test on age revealed significant increases in infants demonstrating object permanence understanding between 9 and 10 months (z = -3.03, p = 0.02).

Figure 5.9 displays the results from the three-level coding scheme.

Figure 5.9

Percentage of Infants who Received Scores of "0", "1" or "2" for Object Permanence Understanding at Each Month



Two out of 25 (8%) infants received a score of "1", and of the 23 infants who received a score of "2", in 1 (4%) case did a score of "1" precede a score of "2". This proportion was different from chance ($p < 0.001$, 95% CI [0.00, 0.22]), indicating that scores of "2" were not consistently not preceded by scores of "1" in the period of observation.

5.2.2.3 Discussion

Overall, the AoEs observed in the object permanence understanding task were similar to results found in previous work (Munakata et al., 1997), with object permanence understanding emerging from 7 months but with a rapid increase in infants demonstrating object permanence understanding between 9 and 10 months. Whilst the coding scheme sought to identify attempts at obtaining the object (scores of “1”), in practice it was challenging to be confident this was the case without being overly inclusive of every interaction with the cloth.

5.3 Gross Motor Capabilities

Whilst the age at which sensorimotor developments occur can vary significantly across individuals and cultures (Adolph & Hoch, 2019), there are two gross motor developments that typically occur in the second half of infants’ first year: independent sitting (sitting without any support from objects or caregivers; Rachwani et al., 2017) and self-locomotion (moving intentionally across the ground and towards desired locations; Walle, 2016). Previous work has suggested that motor developments have important developmental consequences for early communication and language (Anderson et al., 2013; Campos et al., 2000; Iverson, 2010; LeBarton & Iverson, 2016), meaning these are important skills to consider in seeking to understand the origins of joint attention and communication.

5.3.1 Independent Sitting

It is plausible that independent sitting might have an impact on social development. Motor development is influenced by social contexts, and in turn influences social engagements (Adolph & Hoch, 2019). A sitting infant’s hands are free for exploration, and they are positioned in a stable and upright posture (LeBarton & Iverson, 2016). It is plausible that this provides earlier opportunities to interact and communicate face-to-face with caregivers, particularly with manual gestures. By focusing on independent sitting, we refer strictly to those cases in which the infant can sit without the support of another person or object. Previous work has indicated that this ability typically emerges between 5 and 7 months in Western contexts (Karasik et al., 2015).

5.3.1.1 Methods

Procedure. Infants were assessed during two parts of the session. First, infants were coded during the free play session. If the mother decided to start the infant in the support seat, then only the second half of the free play period was coded. Second, infants were coded using the video recording of the maternal interview. During this period, infants were on camera for an extended period, and were often placed on a play mat away from the mother.

Coding. We adopted the definition used by Rachwani and colleagues (2017), whereby the infant is capable of sitting without manual or external support on a flat surface for at least 10 seconds. Table 5.6 details the three-level coding scheme used.

Table 5.6

Behavioural Coding Scheme for Independent Sitting

Score	Description
2	The infant was capable of sitting with no manual or external support (object or mother) for at least 10 seconds.
1	The infant was able to sit independently, but for less than 10 seconds. Or, the infant sat while supporting their own weight with one or two hands.
0	The infant was not capable of independent sitting of any kind.

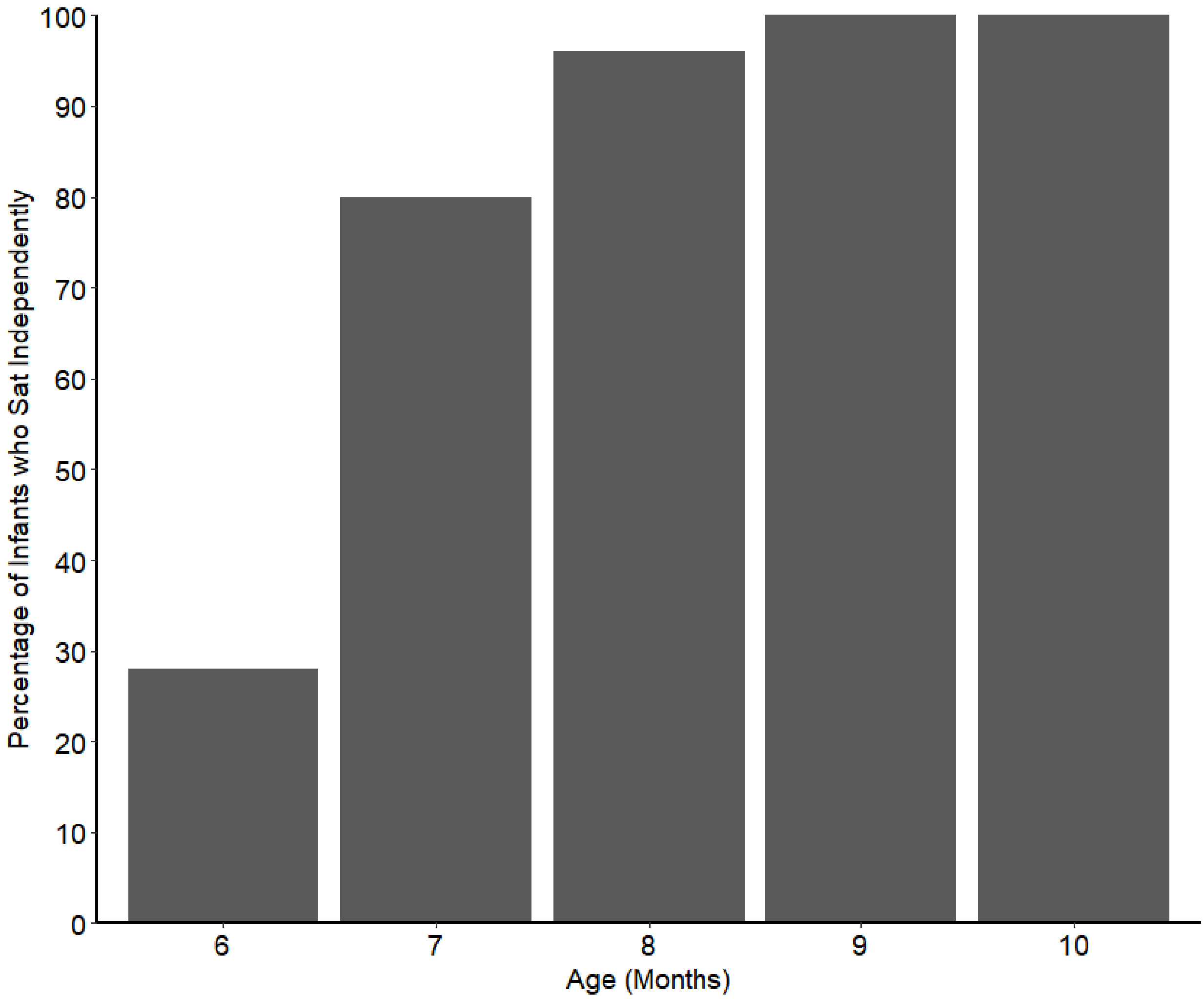
Note. The full version of the coding scheme can be found in Appendix 5A, 5A6.

5.3.1.2 Results

Figure 5.10 displays the cumulative totals of infants who were capable of independent sitting at each month.

Figure 5.10

Cumulative Totals of Infants who Received Scores of "2" for Independent Sitting for each Month



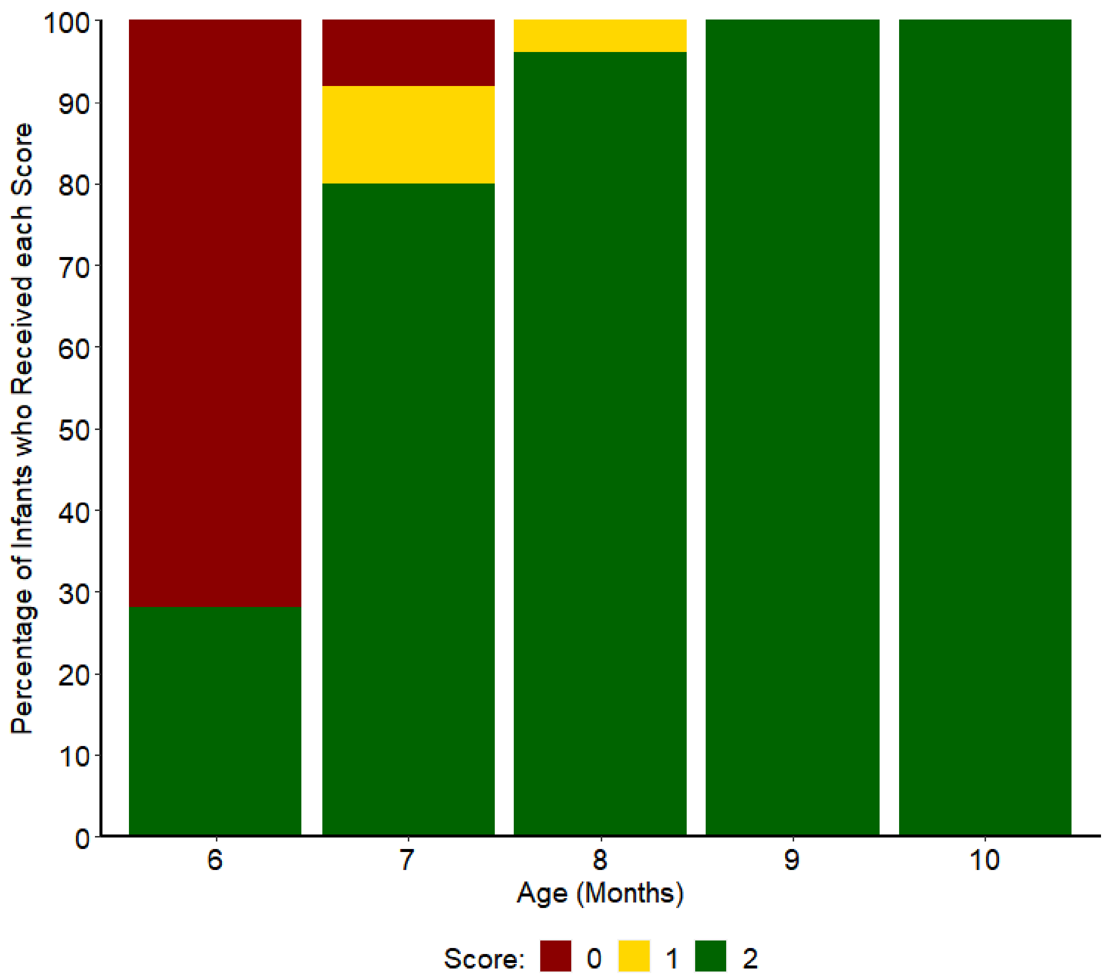
At 6 months, 7 out of 26 (27%) infants could sit independently, and the majority of infants (20 out of 26, 77%) were capable of sitting by 7 months. All infants were capable of sitting by 9 months.

Due to the high numbers of infants that had passed at several sessions, an attempted GLMM ran into convergence issues. Instead, McNemar's tests were used to assess differences between scores at 6 and 7, 7 and 8, and 8 and 9 months. A significant difference was identified between scores at 6 and 7 months ($p < 0.001$).

Figure 5.11 displays the results from the three-level coding scheme.

Figure 5.11

Percentage of Infants who Received Scores of "0", "1" or "2" for Independent Sitting at Each Month



Four out of 25 (16%) infants received a score of "1", and of the 18 infants who received a score of "2" after 6 months (and thus for whom it was possible to establish an ordering of scores), in 4 (22%) cases did a score of "1" precede a score of "2". This proportion was different from chance (*p* = 0.03, 95% CI [0. 60, 0.48]), suggesting that scores of "2" were not consistently preceded by scores of "1" in the period of observation.

5.3.1.3 Discussion

The emergence of independent sitting was in line with the expected range for the sample demographic (Karasik et al., 2015). Independent sitting emerged from at least 6 months of age (possibly sooner in some cases, though this is not possible to tell due to left censoring). The majority of infants were sitting independently by 7 months after a rapid increase in the numbers of infants capable of independent sitting. This suggests that it was common for infants to undergo important motor developments for independent sitting between 6 and 7 months.

Of those infants who were first observed to be capable of independent sitting after 6 months, only 4 out of 18 (26%) received a score of “1” prior to a score of “2”. Part of the reason for this is likely that those infants who were not clearly capable of independent sitting were typically supported by the mother to prevent them from falling over, or were placed on their back or front for the same reason. They may have shown some capacity to sit if given time in a task designed to elicit sitting. In fact, during piloting, a procedure for assessing independent sitting was trialled, but it was found to be difficult to coordinate with the mothers and too time-consuming, and was subsequently dropped. If there had been time to conduct an elicitation procedure, it may have been possible to more accurately assess whether infants were capable of limited independent sitting prior to being capable of independent sitting. However, since fully confident independent sitting was of primary interest here, due to its potential facilitation of postural support and manual freedom, the observational approach taken here was sufficient for the purposes of comparison.

5.3.2 Self-Locomotion

Self-locomotion in particular has been argued to have a profound impact on infants’ social development (Adolph & Hoch, 2019; Anderson et al., 2013; Campos et al., 2000). It has been suggested that the capacity to self-locomote provides infants with a range of new social opportunities and experiences, and these experiences serve to accelerate infants' social development. Our main interest in investigating self-locomotion was to assess whether the ability to intentionally move oneself to a desired location might influence social development, for example (following Campos and colleagues (2000)) by providing more opportunities for distal social engagements, and thus facilitating skills such as communicative gestures, attention following and imitation. The term "self-locomotion" is used as infants are capable of moving themselves in more ways than solely crawling (Anderson et al., 2013; Campos et al., 2000). Previous work has found that the capacity to self-locomote emerges at around 8 to 10 months in cultural and social demographics similar to the sample in the present study, with variability in the form of self-locomotion adopted, such as belly crawling versus hands and knees crawling (Adolph & Hoch, 2019; Adolph et al., 1998).

5.3.2.1 Methods

Procedure. Infants were assessed from the free play period and the maternal interview. Prior to the free play period, mothers were instructed that they and their infant should remain in the room in order to ensure that they were both in view of the two cameras at all times. During the maternal interview, infants were kept in sight of the single camera whenever possible, and when infants did move off screen, it was apparent that they had done so due to their capacity to self-locomote.

Behavioural Coding. The definition of self-locomotion that was used followed Walle (2016), who operationalised the capacity to self-locomote in terms of the distance infants are capable of moving themselves forwards relative to their body length: confident self-locomotion requires the infant to move twice their body length. Table 5.7 details the three-level coding scheme used.

Table 5.7

Behavioural Coding Scheme for Self-Locomotion

Score	Description
2	The infant was capable of self-locomoting forwards for a distance equivalent to or greater than twice the length of the infant's body. Hands-and-knees crawling, commando crawling, scrambling, bum shuffling were all permitted since they involve forward motion; rolling was not.
1	The infant was capable of self-locomoting forwards for a distance of less than twice the length of the infant's body, or the infant self-locomoted backwards.
0	The infant was not capable of self-locomotion, or only moved by rolling.

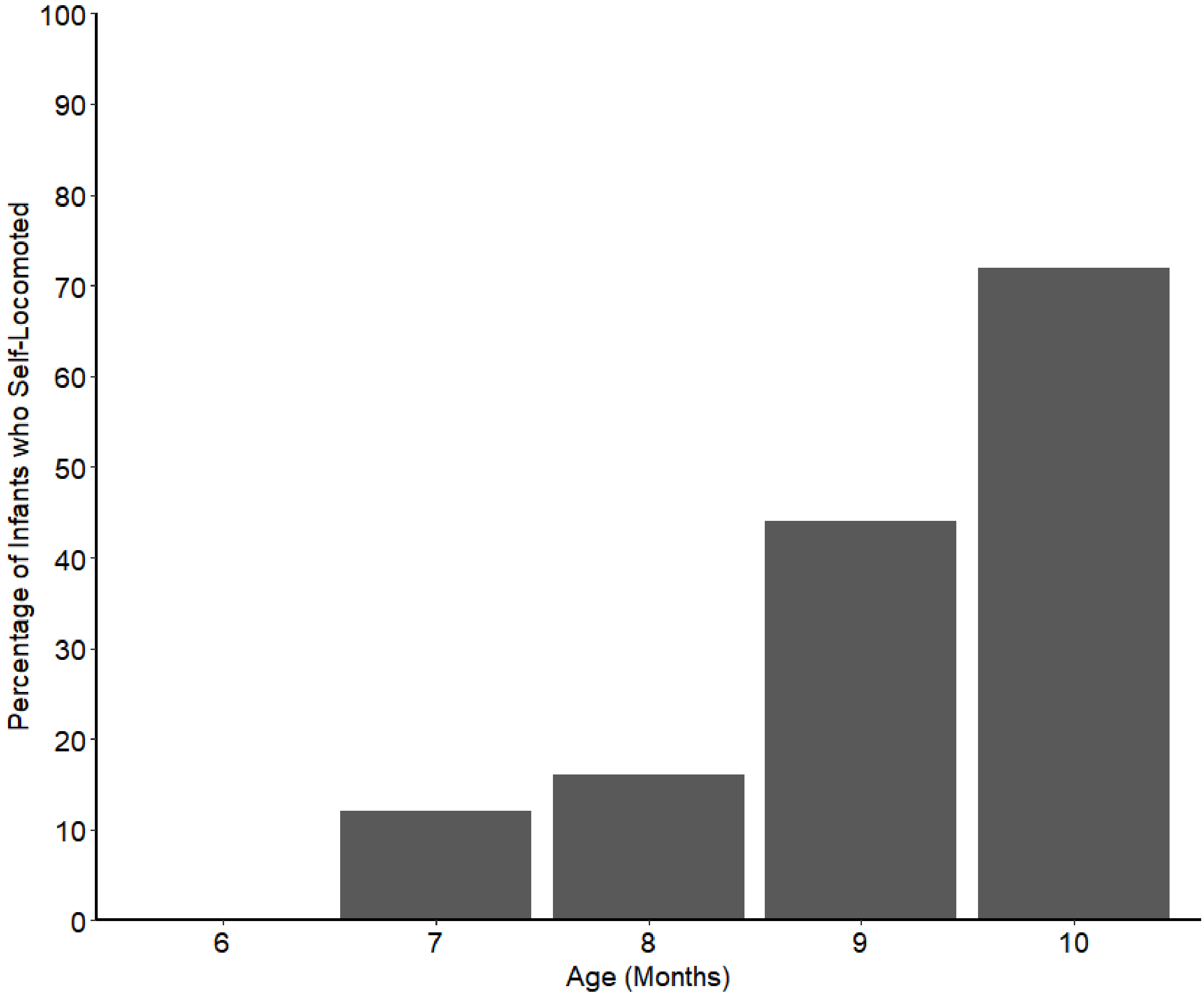
Note. The full version of the behavioural coding scheme can be found in Appendix 5A, 5A7.

5.3.2.2 Results

Figure 5.12 displays the cumulative totals of infants who were capable of self-locomotion at each month.

Figure 5.12

Cumulative Totals of Infants who Received Scores of "2" for Self-Locomotion for each Month



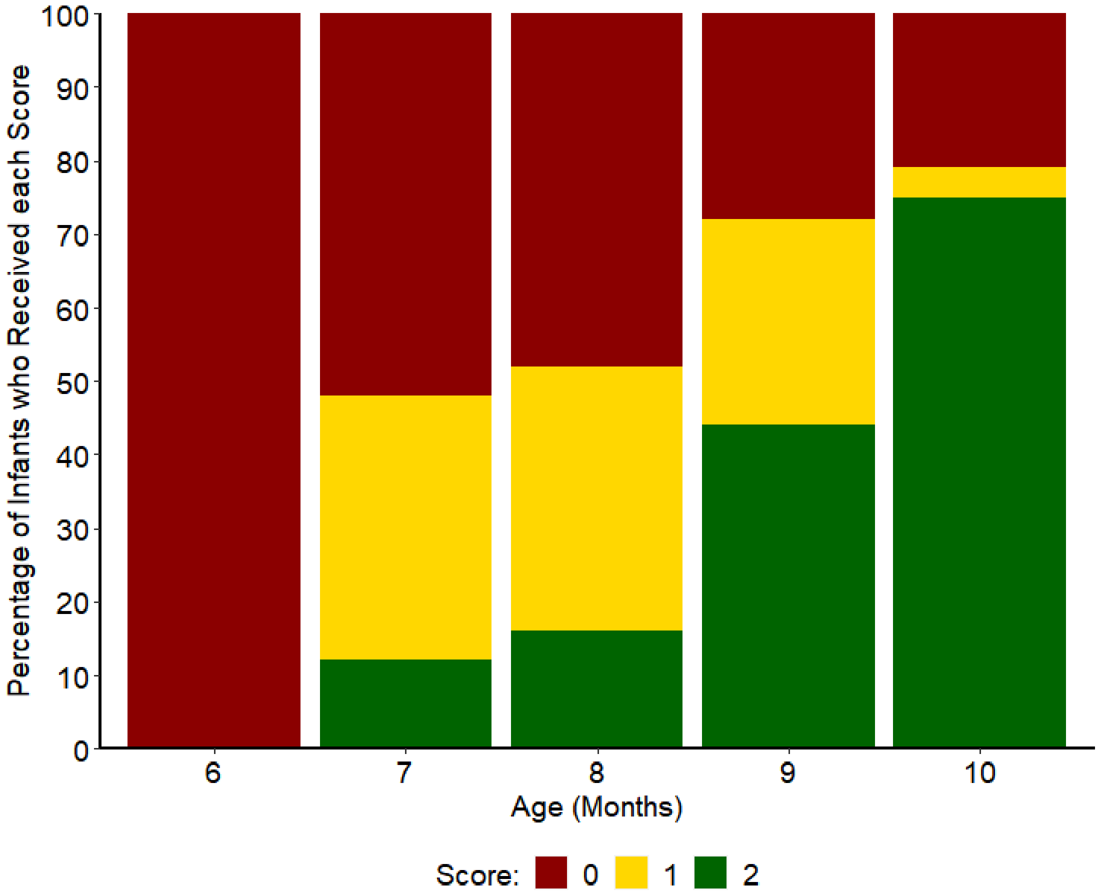
The earliest instances of self-locomotion were observed at 7 months, when 3 out of 25 infants (12%) self-locomoted. The majority of infants (18 out of 25; 72%) could self-locomote by 10 months.

A GLMM was specified in order to examine whether a significant increase in self-locomotion occurred between any consecutive months. The table of model coefficients can be found in Appendix 5B, Table 5B8. A Tukey's HSD post hoc test on age revealed significant increases in infants self-locomoting between 8 and 9 months (z = -3.67, p = 0.002) and between 9 and 10 months (z = -5.33, p < 0.001).

Figure 5.13 displays the results from the three-level coding scheme.

Figure 5.13

Percentage of Infants who Received Scores of "0", "1" or "2" for Self-Locomotion at Each Month



15 out of 25 (60%) infants received a score of "1", and of the 18 infants who received a score of "2", in 14 (78%) cases did a score of "1" precede a score of "2". This proportion

was different from chance (p = 0.03, 95% CI [0.52, 0.94]), suggesting that scores of “2” were consistently preceded by scores of “1” in the period of observation.

5.3.3.3 Discussion

The development of the infants’ self-locomotion was broadly as predicted, with self-locomotion starting to emerge from 7 months, and the majority of infants capable of self-locomotion by 10 months, but with considerable variability in the age at which infants first engaged in self-locomotion (Adolph & Hoch, 2019). A significant increase in infants engaging in self-locomotion was identified between 8 and 9 and 9 and 10 months, suggesting this was the typical age at which infants were undergoing the necessary motor developments that allowed them to self-locomote. However, this does not mean that self-locomotion did not involve gradual development. Given that in a significant proportion of cases, scores of “2” were preceded by scores of “1”, it suggests that there was still a gradual developmental process through which infants became capable of self-locomotion.

5.4 General Discussion

This chapter has presented a range of data on infants’ social understanding, physical cognition and gross motor development. In each case, the majority of infants were capable of the target behaviours by at least 10 months of age, as expected for the cultural demographic of the sample. A rapid increase between consecutive months in infants producing social behaviours was not observed. However, there were rapid increases in the cognitive and motor tasks.

CHAPTER 6

THE DEVELOPMENTAL EMERGENCE AND INTERRELATIONS OF COMMUNICATIVE, SOCIAL AND MOTOR ABILITIES BETWEEN 6 AND 10 MONTHS

The previous chapters have focused on a range of abilities that are relevant to the development of joint attention and communication in infancy. This chapter draws together the various abilities that have been assessed across the previous chapters, in order to explore the overall patterns that can be identified in the 6 to 10 month period. There are three key issues to be addressed: the relative ordering of emergence of these abilities, the suddenness of the emergence of these abilities, and interrelations amongst these abilities. By furthering our understanding of the very beginnings of these abilities, different theories regarding the development of joint attention and communication can be scrutinised, which in turn facilitates progress in conceptual discussions.

A number of studies have sought to investigate infants' capacity to engage in joint attention and other early social and cognitive abilities (Bates et al., 1979; Beuker et al., 2013; Carpenter et al., 1998; Matthews et al., 2012; Salo et al., 2018; Slaughter & McConnell, 2003). Despite providing important insights into the emergence of and relation amongst infants' social and cognitive abilities, these studies have typically started at around 8 or 9 months or later, which this study and others have shown to be too late to catch the very beginnings of these abilities. Work led by Striano and colleagues has sought to shift attention to the developments that occur prior to 9 months (De Groote et al., 2007; Striano & Bertin, 2005b, 2005a; Striano & Rochat, 2000; Striano et al., 2009; for a review, see Hoehl & Striano, 2013). However, there are a number of key issues still to be addressed.

The first key issue is the relative order of emergence of joint attention, communication and other relevant abilities. Whilst the claim that joint attention emerges after 9 months is still commonplace (e.g. Gabouer & Bortfeld, 2021; Tomasello, 2019), the work of Striano and colleagues' (Striano & Bertin, 2005a; Striano et al., 2009) has provided some support for the view that infants can initiate joint attention through what they label "joint engagement looks with smile" (Striano & Bertin, 2005a, p. 784) or "smiles during coordinated visual attention" (Striano et al., 2009, p. 584). Similarly, Jones & Hong (2001) found that some infants were capable of communicative looks at 8 months of age. Likewise, research on attention following (Bertenthal et al., 2014; D'Entremont, 2000; D'Entremont et al., 1997; Gredebäck et al., 2010; Meltzoff & Brooks, 2007; Shepherd, 2010; Striano & Stahl, 2005) and imitation (Barr et al., 1996; Carpenter et al., 1998; Jones, 2007; Striano et al., 2009) have identified different AoEs for these abilities. Some argue that the abilities start to emerge prior to 9 months and others arguing that they emerge only after. The most consistent finding is that communicative gestures first start to emerge at around 9 to 10 months (Bates et al., 1979; Cameron-Faulkner et al., 2015; Carpenter et al., 1998; Stephens & Matthews, 2014), though there is still variability in AoE across infants.

There is also evidence that cognitive abilities such as means-ends understanding and object permanence understanding emerge prior to 9 months (Moore & Meltzoff, 1999; Munakata et al., 1997; Sommerville & Woodward, 2005; Striano et al., 2009; Willatts, 1999). Finally, there are important motor developments occurring before and around 9 months. Infants are typically capable of independent sitting by 5 to 7 months (Karasik et al., 2015), and are typically capable of self-locomotion by 8 to 10 months (Anderson et al., 2013; Campos et al., 2000).

Overall, it is apparent that there is evidence that a range of important joint attention and other abilities start to emerge prior to 9 months, and of those that typically emerge at around 9 months, there is variability across infants. Thus, examining these various abilities in a single sample of infants will enable an insight into the relative ordering of abilities.

The second key question relates to the suddenness of emergence of key social and communicative abilities: do they emerge suddenly or more gradually? Various researchers have argued that infants undergo sudden developments in joint attention and communication at around 9 months, labelled as the “9-month revolution” by Tomasello (1999). It is typical for those focusing on a sudden change to suggest that this is a shift in the infant’s cognition or intelligence (Carpenter et al., 1998; Stern, 1985; Tomasello, 1999; Trevarthen & Hubley, 1978). Trevarthen and Hubley (1978) argue that the transitions that occur at 9 to 10 months are so consistent across different infants that there must be an underlying shift in intelligence that is innate and emerges due to maturation rather than through social experience. Tomasello (1999, 2019) similarly states that it is a sudden cognitive shift, which allows infants to understand others as intentional agents. This leads to qualitatively different forms of interaction that are distinct from those in which infants were previously engaged (Tomasello, 1995, 2019).

The alternative view is that there is no such sudden shift, with a more gradual development of early social and cognitive abilities (Bakeman & Adamson, 1984; de Barbaro et al., 2013; Hoehl & Striano, 2013; Moll et al., 2021). These arguments take various forms, with researchers acknowledging that important developments occur at around 9 months, but providing evidence for gradual developmental changes underpinning this change. Striano and colleagues (2009) draw from free play observations and behavioural tasks to provide evidence that infants start to engage in joint attention from around 7 months (though as young as 5 months) with a gradual increase in the production of joint attention abilities. de Barbaro and colleagues (2013; 2016) present evidence that the gradually-developing ability to decouple visual and manual attention can explain the emergence of triadic joint attention and other social abilities that emerge at around 9 months.

The issue of suddenness is closely related to the final key issue: that of the interrelations amongst early social, communicative and other abilities. Typically, accounts that emphasise a sudden developmental transition also argue for interrelations amongst a range of different abilities. For example, Tomasello (1999) argues that the social developments that occur at 9 month are associated, as they are all underpinned by a common cognitive capacity to understand others' intentions. This view is built on some prior evidence for relations between social and communicative abilities emerging at around 9 months (Bates et al., 1979; Carpenter et al., 1998). Bates and colleagues found interrelations amongst different communicative gestures and between communicative gestures and imitation (vocal and gestural). They also found that means-ends understanding was associated with communicative gestures. Carpenter and colleagues (1998) sought to expand on this research to examine if the relations amongst social abilities went beyond those identified of Bates and colleagues. They found relations amongst a wide range of social abilities, including joint engagement (operationalised using gaze alternation), communicative gestures, attention following, imitative learning and referential language. However, Carpenter and colleagues (1998) themselves acknowledge that the correlations they identify were not as strong as they expected and were predicted by the 9-month revolution account. This provides something of a caveat for this data serving as straightforward evidence of a 9-month revolution.

An alternative approach is that there are no such widespread interrelations (Carpendale & Lewis, 2004; Racine & Carpendale, 2007). Research that has questioned previous claims regarding close developmental relations amongst social and cognitive abilities. For example, Slaughter and McConnell (2003), using a cross-sectional approach, found no relations amongst a range of joint attention abilities (including gaze following, social referencing and imitation). Striano and colleagues' (2009) longitudinal study found some limited relations between the AoE of various social abilities (such as between gaze following and imitation, between coordinated visual attention and imitation, and between coordinated visual attention and coordinated visual attention with smiles) but with no clear pattern as to why these AoEs might be related.

A final approach is that clusters of abilities that are related. For example, some researchers have proposed dividing joint attention skills into those involved with initiating joint attention ("IJA" (Seibert et al., 1982); e.g. showing and declarative pointing gestures), and those involved in responding to joint attention ("RJA"; e.g. gaze and point following). It has been found that these groups of abilities rely on different cognitive and neural bases (Mundy & Gomes, 1998; Mundy & Newell, 2007; Salo et al., 2018). These accounts argue that IJA and RJA have different neural and cognitive bases, thus predicting that IJA abilities are developmentally associated and that RJA abilities are developmentally associated, but that there are no relations between IJA and RJA abilities (Mundy & Gomes, 1998; Mundy & Newell, 2007; Salo et al., 2018). Various studies have provided evidence that developmentally earlier IJA abilities do indeed predict the emergence of later IJA abilities. They show that the use of gaze alternation to initiate joint attention predicts declarative gestures (showing and pointing), which in turn predict language skills (Carpenter et al., 1998; Choi et al., 2021; Salo et al., 2018).

However, some previous work has suggested that the difference between IJA and RJA cannot account for previously identified relations amongst different skills. For example, both Salo and colleagues (2018) and Carpenter and colleagues (1998) found a relation between RJA and communicative gesture production, whilst Striano and colleagues (2009) found RJA was related to imitation. Thus, even if it is not the case that social developments occurring in the latter half of infants' first year are not all underpinned by a single shift in cognitive capacity, it may be that the relations amongst different abilities cannot be fully accounted for by positing a separation between IJA abilities and RJA abilities (Salo et al., 2018).

To summarise, there are three key overall issues to be addressed:

1. *Relative ordering of emergence*: When do the assessed social, cognitive and motor abilities emerge, and in what sequence?
2. *Suddenness of emergence*: Do these abilities emerge suddenly or more gradually?
3. *Interrelations amongst abilities*: What are the relations between the different abilities that emerge? Are the assessed social abilities all related, are there clusters of related abilities, or are there no relations amongst different abilities?

Whilst some studies have addressed elements of these questions, this study adds several novel contributions. First, it assesses infants from earlier than most previous work, starting at 6 months of age. Second, it includes assessments of key abilities that have not been examined in relation to joint attention, or have only been assessed from free play. In the social domain, assessments of joint attention looks that used experimental tests were used (see Chapter 3), and a range of communicative gestures were considered (see Chapter 4). This study included assessments of gross motor abilities (independent sitting and self-locomotion), which were not included in any capacity in previous studies that consider the development of joint attention and communication.

There are a range of predictions to outline. The first pertain to the orders of emergence. Based on previous work, it was expected that the social abilities of attention following, imitation and communicative gestures would all emerge after 9 months. Previous evidence for joint attention looks was more mixed, with some work suggesting this ability emerges prior to 9 months (Striano & Bertin, 2005a; Striano et al., 2009) and other work suggesting it only starts to emerge later than 9 months (Carpenter et al., 1998). It was predicted, based on previous findings that the assessed cognitive abilities would start to emerge prior to 9 months (Striano et al., 2009). Finally, based on previous findings, it was expected that independent sitting would emerge early in the assessed age range (i.e. 6 to 7 months) (Karasik et al., 2015), with self-locomotion emerging between 8 to 10 months (Adolph & Hoch, 2019; Adolph et al., 1998).

Regarding the suddenness of emergence, it would be expected to observe a sudden increase in infants producing the assessed social abilities at around 9 months if indeed there was a psychological revolution. Alternatively, if there was no such revolution, it would be expected that there were no sudden increases in the number of infants starting to engage in the social abilities. Whilst the focus was not on the suddenness of emergence for the assessed cognitive abilities, there is some previous evidence suggesting means-ends understanding emerges suddenly. Finally, motor abilities were predicted not to emerge suddenly (Adolph et al., 2008).

The predictions for interrelations can be sorted into three groups. First were associations between social abilities. Following the predictions of a “9-month revolution”, relations amongst the assessed social abilities (joint attention looks, gestures, imitation, and attention following) would be expected. Alternatively, following those who argue for no consistent relations between joint attention abilities, we would expect no relations to be observed. The final plausible prediction is that there are relations between IJA skills, including joint attention looks and declarative gestures. Since it was not clear that the identified giving gestures were necessarily declarative, and we did not observe any pointing gestures, we drew upon the data for showing gestures alone as gestures that had been coded as declarative.

Second were associations between cognitive and social abilities. It was predicted that the AoE of means-ends understanding would be associated with the AoEs of communicative abilities, including joint attention look, communicative gesture and imitation, based on previous research that has identified these relations (Bates et al., 1979; Carpenter et al., 1998; Jones & Hong, 2001). It was also predicted that object permanence understanding AoE would not be associated with the AoEs of social abilities (Bates et al., 1979; Carpenter et al., 1998).

Third and finally were associations between motor and social abilities. In light of previous work suggesting that the onset of independent sitting (LeBarton & Iverson, 2016) and self-locomotion (Anderson et al., 2013; Campos et al., 2000) influence social development, correlations between the assessed motor ability AoEs and social ability AoEs were assessed. In particular, it was predicted that the AoE of independent sitting would correlate with the AoE of communicative gestures by enabling infants to have freer use of their hands, though it was plausible that it would also be associated with other social abilities by the same token. Given previous claims that the onset of self-locomotion facilitates is associated with changes in social interaction (Anderson et al., 2013; Campos et al., 2000) it was predicted that the AoE of self-locomotion would be potentially be associated with the AoE of the assessed social abilities.

6.1 Method

The data here are drawn from Chapters 3, 4 and 5. The abilities included joint attention looks (Chapter 3), communicative gestures (Chapter 4), imitation, attention following, means-ends understanding, object permanence understanding, self-locomotion, and independent sitting (Chapter 5). Due to low numbers of infants engaging in the different imitation and attention following tasks, an overall score is given for each of these abilities (i.e. the earliest instance of the ability was used, regardless of what kind of communicative, and whether it was dyadic or triadic imitation, or gaze or point following).

6.1.1 Analyses

The analysis of the dataset aimed to assess the relative order of the ages of emergence (AoEs) of the different abilities assessed, the suddenness of emergence of the different abilities and any interrelations amongst the AoEs of the different abilities. For the coding scheme that has been applied in previous chapters, these are generated using the first age at which the infant received a score of “2”. For a comparable analytic approach, see Striano et al. (2009).

6.1.1.1 Analysis of the Relative Ordering of Emergence

The first analyses addressed the relative ordering of the AoEs of the different abilities. The population-level pattern of emergence of the different abilities was assessed using Kaplan-Meier survival analysis (Clark et al., 2003). Survival analysis is suited to time-to-event data, generating a distribution of the probability over time that some event will occur, as well the median time for that event (the time at which 50% of the population would be expected to have experienced the event). Here, the event of interest is the first instance of a behaviour (e.g. first instance, i.e., AoE, of self-locomotion). Survival analysis is equipped to deal with right-censoring (see Chapter 2), as censored events still contribute to the survival distribution’s hazard rate (that is, the probability that the event will occur over time; Clark et al., 2003). Survival analyses and visualisations were conducted using the R packages survival (Therneau, 2021) and survminer (Kassambara, 2021). Survival curves are more easily interpreted when there is more variation in the time values. For this reason, the number of days old infants were at the session at which they produced the target behaviours were used rather than the closest month of emergence. Because data were collected for imitation and communicative gestures at 11 and 12 months, these were included in the analysis. Finally, pairwise Wilcoxon matched-pairs signed-ranks tests were conducted to assess whether there were significant differences between AoEs for each pair of tasks. Wilcoxon tests are non-parametric and robust with censored observations. Significant differences indicated that one task emerged consistently earlier than the other.

6.1.1.2 Analysis of Suddenness of Emergence

The next set of analyses focused on identifying sudden increases in the number of infants who engaged in the assessed abilities. Sudden increases were operationalised as a significant increase in the number of infants who produced the assessed ability between consecutive months. The analyses and models are detailed in Chapters 3, 4 and 5, and their appendices.

6.1.1.3 Analysis of AoE Interrelations

The final analyses focused on associations between the AoEs of the different behaviours. In some previous studies, monthly cross-lagged correlations (either using pass/fail measures (Carpenter et al., 1998) or count measures (Bates et al., 1979)) have been used to assess month-to-month associations. However, cross-lagged correlations fail to account for autocorrelation (the fact that an individual's production of a behaviour will correlate with their own previous production of that behaviour; see 2.4.3.2). Thus, the strategy used here is instead to assess correlations between the AoEs of the different abilities, to infer relations between the emergence of these abilities (for an example of this approach, see Striano et al., 2009). Correlational analyses were used as, almost all abilities, the AoE order was not consistent (i.e. neither ability always emerged first for every participant). This meant that regression analyses were not appropriate; due to their conceptualisation as predictive models, it would be necessary for the AoEs to always occur in the same order.

Rather than assigning an arbitrary later age as an AoE for right-censored cases (see Striano et al., 2009) we either dropped that data from the analysis, or drew upon data collected at 11 and 12 months from maternal questionnaires to assign an AoE if the ability had not been observed to emerge previously. Data were available for imitation, showing gestures, and communicative gestures at 11 and 12 months. For other cases, right-censored data were dropped in the analysis. For cases of left-censoring (where a behaviour was observed, but it could not be clearly established if it had emerged earlier than 6 months) two options are provided; a more conservative approach where left-censored cases are dropped (with the disadvantage of reducing the sample size), and another approach where left-censored cases are included (with a larger sample size, but with left-censored cases potentially influencing the results). Descriptive statistics indicated that the AoE scores for each behaviour were not normally distributed, except for the AoE of communicative gestures. Thus a non-parametric test of association, Spearman's rank correlation coefficient, was calculated in each case. Not all possible combinations of tasks were relevant, and assessing every possible combination would require correcting results for multiple comparisons, weakening the ability to detect relevant correlations. Thus, only planned analyses that were hypothesised to be of interest were calculated.

6.2 Results and Discussion

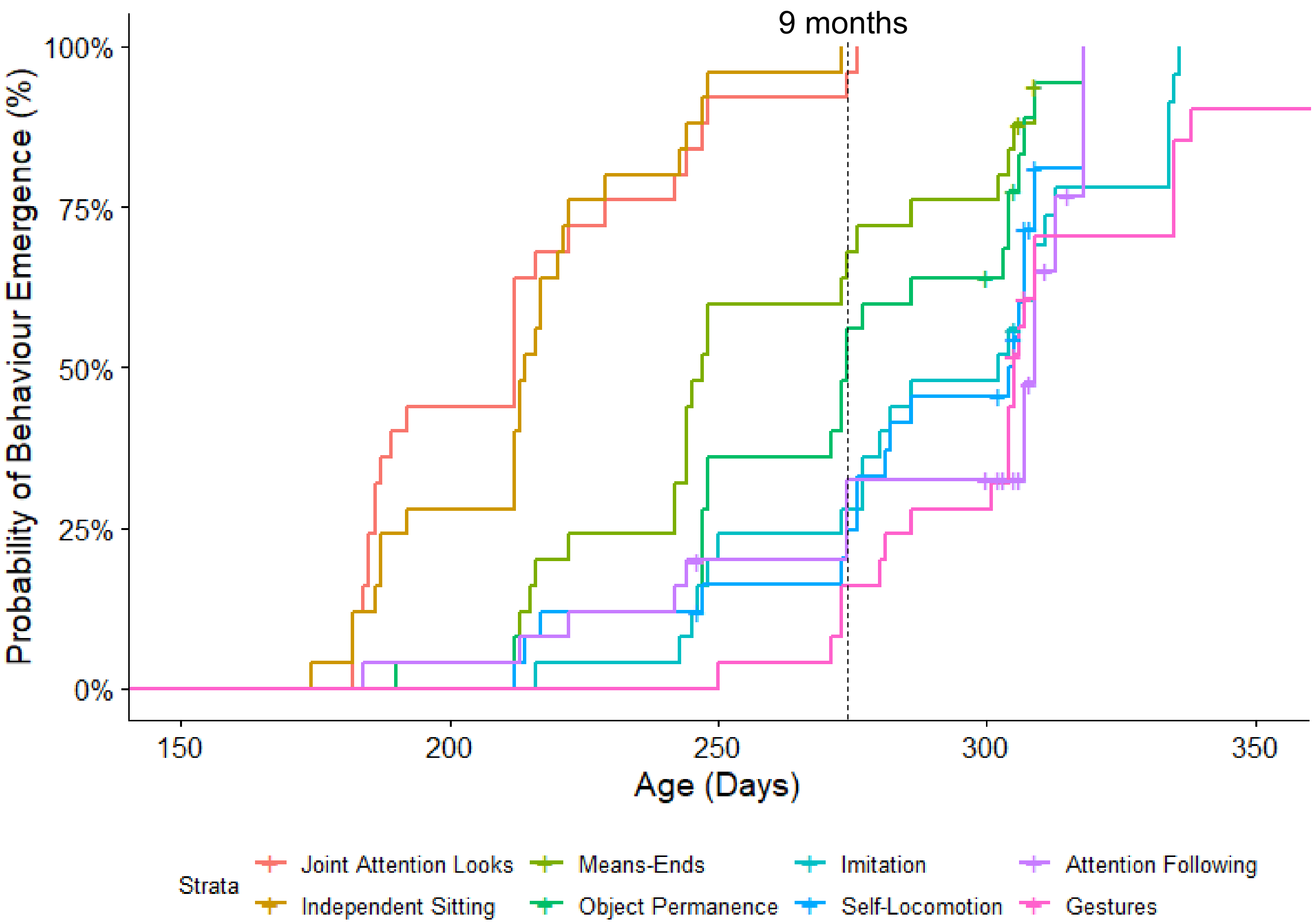
6.2.1 Relative Orderings of Ages of Emergence

The following figures and table depict when the various abilities emerged within the period of assessment, and whether there was a significant difference between the AoEs. The survival distributions for each assessed ability are displayed in Figure 6.1. Table 6.1 shows pairwise comparisons of the AoEs of each ability, assessing significant differences between ability AoEs. Table 6.2 combines these two previous visualisations to display the overall ordering of the AoEs for each behaviour type.

Earliest emerging were joint attention looks and independent sitting. Next, means-end understanding and object permanence understanding emerged. However, object permanence understanding did not emerge significantly earlier than imitation, self-locomotion and attention following, though it did emerge earlier than communicative gestures. Finally, the AoEs of imitation, self-locomotion, attention following and communicative gestures did not significantly differ from each other.

Figure 6.1

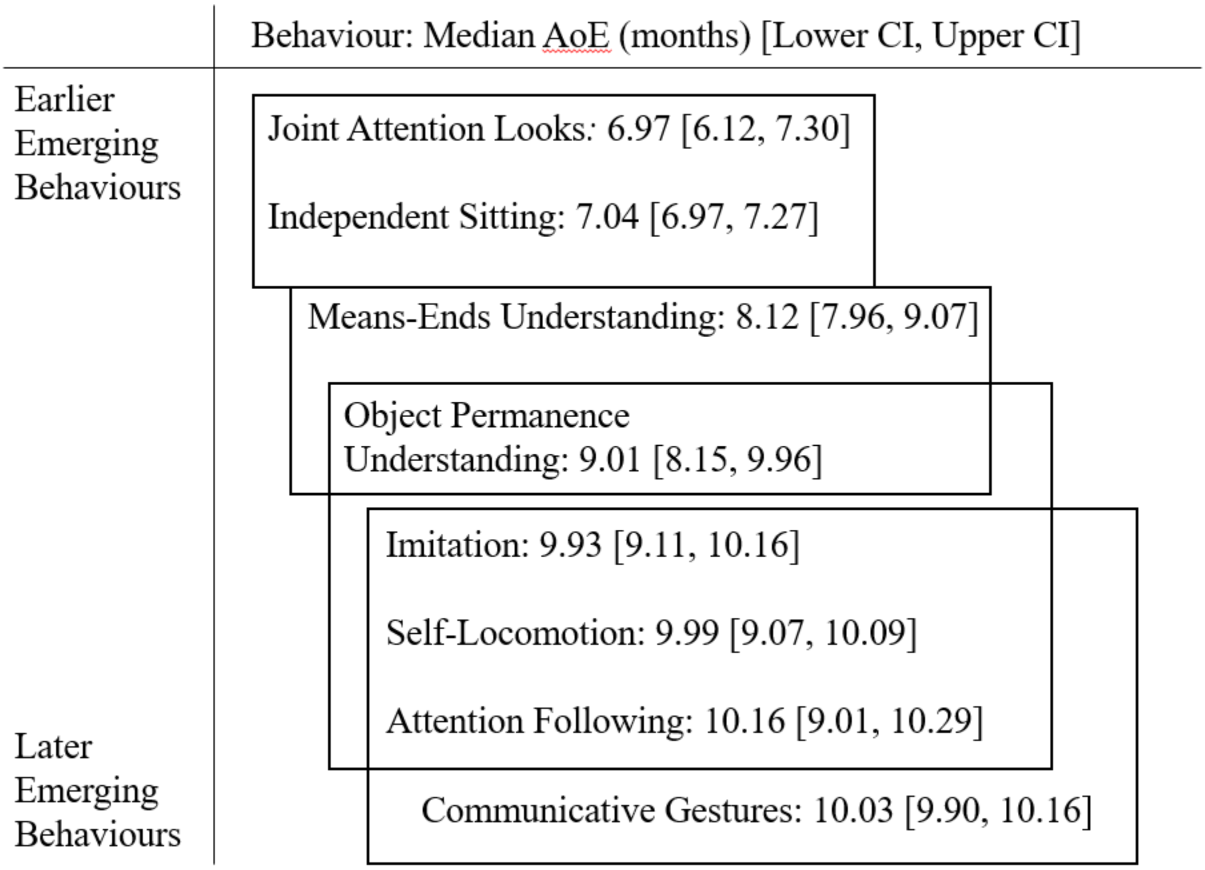
Survival Distributions of All Assessed Behaviours



Note. Independent sitting and joint attention look curves are not left-censored. Crosses (+) indicate right-censored events. The vertical dashed line marks 9 months of age.

Figure 6.2

Overall Ordering of Ages of Emergence for All Behaviours



Note. Behaviours within the same box do not have significantly different median AoEs as calculated using Wilcoxon tests. CIs were calculated on the log-log scale. Note that because of differing numbers of censored events, a significant difference between the median AoE of means-ends understanding and communicative gestures was observed despite the overall median AoE of communicative gestures being lower than that of attention following.

Table 6.1

Wilcoxon Matched-Pairs Signed-Ranks Test Comparing Ages of Emergence for All Tasks

	Joint Attention Looks	Independent Sitting	Means-Ends Understanding	Object Permanence Understanding	Imitation	Self-Locomotion	Attention Following
	p	*p*	*p*	*p*	*p*	*p*	*p*
Independent Sitting	0.45	-	-	-	-	-	-
Means-Ends Understanding	<0.001***	<0.001***	-	-	-	-	-
Object Permanence Understanding	<0.001***	<0.001***	0.15	-	-	-	-
Imitation	<0.001***	<0.001***	0.003**	0.08	-	-	-
Self-Locomotion	<0.001***	<0.001***	0.01*	0.15	0.46	-	-
Attention Following	<0.001***	<0.001***	0.01*	0.13	0.62	0.63	-
Communicative Gestures	<0.001***	<0.001***	<0.001***	0.002**	0.25	0.12	0.25

Note. ***$p < 0.001$, **$p < 0.01$, **$p < 0.05$.

Table 6.2

Relative Ordering of AoEs for each Ability Combination

	Joint Attention Looks	Independent Sitting	Means-Ends Understanding	Object Permanence Understanding	Imitation	Self-Locomotion	Attention Following
Independent Sitting	10/6/9	-	-	-	-	-	-
Means-Ends Understanding	18/3/4	17/3/5	-	-	-	-	-
Object Permanence Understanding	19/4/2	20/1/4	13/6/6	-	-	-	-
Imitation	24/0/1	22/2/1	17/5/3	14/7/4	-	-	-
Self-Locomotion	21/1/3	21/0/4	14/3/8	11/5/9	12/11/2	-	-
Attention Following	20/3/2	23/1/1	16/4/5	15/6/4	16/5/4	9/9/7	-
Communicative Gestures	25/0/0	25/0/0	18/4/3	13/3/9	12/6/7	10/8/7	10/12/3

Note. For each combination, the first number represents the number of participants for whom the ability listed in the column heading emerged earlier than the ability listed in the row heading. The second number represents the number of participants for whom the ability listed in the column heading emerged later than the ability listed in the row heading. The third number represents the number of participants for whom the abilities listed in the column and row headings emerged in the same month, or were both censored. For example, for 10 participants joint attention looks had an earlier AoE than independent sitting, for 6 participants joint attention looks had a later AoE than independent sitting, and for 9 participants these abilities emerged in the same month.

In summary, joint attention looks and independent sitting were clearly the earliest abilities to emerge, with median AoEs of approximately 7 months. It is important to note that this is without left-censoring, which means the true median values may possibly be lower. However, this does not change the overall interpretation of the results, as the survival distribution of these abilities would only move earlier in that case and thus only become more significantly different from the other distributions. Given that the assessments of these behaviours were both impacted by left-censoring, it is possible that there are differences in their AoEs that would emerge if these abilities were assessed from an earlier age. In almost all cases, there was variability in the relative orderings of AoEs. The only exceptions were that the AoE of joint attention looks and independent sitting were earlier than the AoE communicative gestures for all participants, the AoE of joint attention looks and independent sitting was earlier or equal to the AoE of imitation for all participants.

Joint attention looks emerged first out of all the assessed social behaviours. It is also notable that joint attention looks emerged earlier than means-ends understanding, particularly given prior findings of a relation between means-ends understanding and communicative abilities (Jones & Hong, 2001). However, it would be premature to completely rule out the role of means-ends understanding in joint attention looks. It is possible that joint attention looks involve an implicit or rudimentary grasp of means-ends that is only later expressed in action (Munakata et al., 1997). Means-ends understanding typically emerged prior to the other assessed social abilities, indicating that means-end understanding is typically online prior to the emergence of gestures, imitation and attention following.

There were no differences between the survival distributions of object permanence understanding, imitation, gestures, self-locomotion and attention following. In the majority of cases, these behaviours emerged after 9 months, and all were later than joint attention looks, independent sitting and means-ends understanding.

Finally, some previous research has found that self-locomotion is the catalyst for a range of social developments (Anderson et al., 2013; Campos et al., 2000). However, the findings here suggest that many of the key social developments in this period are emerging at around the same time, and not consistently later, than self-locomotion. Whilst it is still plausible that self-locomotion has an influence on later social development by providing new social situations and providing the infant with greater agency, these findings suggest that many of the key social developments in the infants' first year are not consistently emerging after the onset of self-locomotion, suggesting it does not play a key role in the emergence of these abilities.

6.2.2 Suddenness of Emergence

The next issue to be addressed is whether the assessed behaviours emerged suddenly or gradually during the period of assessment. These results have been presented in previous Chapters (3, 4 and 5), so are collated here. Table 6.3 presents the findings regarding any sudden changes, indexed by a significant increase the number of infants producing an ability between consecutive months.

Table 6.3

Developmental Profile of Assessed Social, Cognitive and Motor Abilities

Behaviour	Sudden increase?	Ages
Joint Attention Looks	No	NA
Communicative Gestures	No	NA
Showing Gestures	No	NA
Giving Gestures	No	NA
Request Gestures	No	NA
Pointing Gestures	NA	NA
Attention Following	No	NA
Gaze Following	No	NA
Point Following	No	NA
Imitation	No	NA
Triadic Imitation	No	NA
Dyadic Imitation	No	NA
Means-ends Understanding	Yes	7 and 8 months
Object Permanence Understanding	Yes	9 and 10 months
Independent Sitting	Yes	6 and 7 months
Self-Locomotion	Yes	8 and 9 months, 9 and 10 months

As Table 6.3 indicates, there was no sudden increase in infants engaging in any of the assessed social abilities. The only sudden increases occurred in the cognitive abilities (both means-ends understanding and object permanence understanding) and the motor abilities (independent sitting and self-locomotion).

These results do not align with the hypothesis of sudden developments occurring from 9 months (Tomasello, 1999), instead favouring the view that social abilities emerge gradually during the second half of infants' first year (Bakeman & Adamson, 1984; de Barbaro et al., 2013; Hoehl & Striano, 2013; Moll et al., 2021). None of the assessed social abilities emerged in the population in a sudden manner, here meaning a significant increase in the number of infants engaging in that ability between consecutive months.

However, it is also important to focus on individual-level patterns of development. One pattern that was observed frequently was that infants produced an ability at one session, but then not at the following session, before producing the ability again at a later age. This pattern was also observed in Striano and colleagues (2009), using weekly assessments. An important issue for future work is thus to explore whether these incidents involved genuine variation in infants' ability production, or were perhaps due to variations in mood or other extraneous factors, this issue should receive more attention in future work. Additionally, the focus could not only be on the production of key behaviours, but on the consistency of their production. A finding identified in Chapter 3 was that there was a gradual increase in how consistently infants produced joint attention looks between 6 and 10 months. This suggests that the ability did not emerge suddenly in an all-or-nothing manner in individual infants, but rather that there was a process through which infants became more consistent in this ability. If there is indeed a "revolution" in these abilities, one might expect a rapid shift from no competence to developed competence in a tight timeframe. Whilst this was not the case for joint attention looks, it is not clear if it was the case for the other assessed abilities (either due to only one task being used to assess the ability, or due to insufficient numbers of responses to model the number of, for example, communicative gestures produced).

In contrast, all of the cognitive and motor abilities that were assessed had periods in which there was a significant increase in the number of infants engaging in the ability. There is previous evidence that cognitive abilities, particularly means-ends understanding, emerge suddenly (Striano et al., 2009). However, a range of evidence has been collected that has demonstrated the gradual nature of motor development, which makes this finding somewhat surprising (Adolph & Hoch, 2019; Adolph et al., 2008). These patterns are like due to the way in which these abilities were assessed, with relatively broad categories applied rather than using a number of more refined categories (e.g. splitting belly crawling and hands-and-knees crawling), meaning that the changes appeared sudden despite being preceded by a gradual developmental process.

6.2.3 Interrelations amongst Ages of Emergence

In the next set of analyses, the focus is on associations between the AoEs of different behaviours. The first set of comparisons examines the relations between the assessed social abilities. Table 6.4 displays the matrix of correlation coefficients.

Table 6.4

Associations between Social Ability AoEs using Spearman's Rank Correlation Coefficient (ρ)

Behaviours	Gestures		Showing Gestures		Imitation		Attention Following	
	n	*ρ [95% CI]*	*n*	*ρ [95% CI]*	*n*	*ρ [95% CI]*	*n*	*ρ [95% CI]*
Imitation	23	0.00 [-0.38,0.42]	22	0.10 [-0.31,0.51]		-		-
Attention Following	14	0.20 [-0.38,0.77]	14	0.06[-0.54,0.66]	15	-0.44[-0.83,0.19]		-
Joint Attention Looks	23	0.13 [-0.30,0.55]	22	0.29 [-0.22,0.65]	24	0.32[-0.13,0.65]	15	-0.46 [-0.94,0.12]
Left-Censoring Applied	13	0.27 [-0.34,0.76]	13	0.54* [-0.07,0.85]	14	0.21[-0.36,0.71]	9	0.08 [-1.00,0.83]

Note. *$p < 0.05$. All behaviour AoEs are right-censored, leading to different *n* values.

The only significant correlation was found between joint attention looks and showing gestures, with the more conservative approach to left-censoring taken. However, it is worth noting the substantially reduced sample size due to dropping of left-censored events. This is reflected in the wide confidence intervals for the correlation coefficient. All other associations were non-significant.

The next set of comparisons examine the relations between the assessed social and cognitive abilities. Table 6.5 displays the matrix of correlation coefficients.

Table 6.5

Associations between Social Ability AoEs and Cognitive Ability AoEs using Spearman's Rank Correlation Coefficient (ρ)

Behaviours	Means-Ends Understanding		Object Permanence Understanding	
	n	*ρ [95% CI]*	*n*	*ρ [95% CI]*
Joint Attention Looks	23	-0.14[-0.53,0.32]	23	-0.56**[-0.80,-0.21]
Left-Censoring Applied	14	-0.15[-0.66,0.43]	14	-0.24[-0.61,0.28]
Communicative Gestures	21	-0.07[-0.50,0.39]	22	-0.34[-0.65,0.10]
Showing Gestures	21	-0.03[-0.48,0.44]	21	-0.30[-0.68,0.17]
Imitation	22	0.26[-0.22,0.64]	23	-0.23[-0.61,0.28]
Attention Following	14	-0.01[-0.60,0.53]	15	0.29[-0.33,0.71]

Note. ***p* < 0.01. All behaviour AoEs are right-censored, leading to different *n* values.

A significant negative correlation was identified between Joint Attention Looks and Object Permanence Understanding without left-censored cases removed.

The final set of comparisons examines the relations between the assessed gross motor abilities and the assessed social abilities. Table 6.5 displays the matrix of correlation coefficients, including left-censored scores where relevant.

Table 6.6

Associations between Social Ability AoEs and Motor Ability AoEs using Spearman's Rank Correlation Coefficient (ρ)

Behaviours	Independent Sitting		Self-Locomotion	
	n	*ρ [95% CI]*	*n*	*ρ [95% CI]*
Gestures	22	0.27[-0.16,0.62]	17	-0.03 [-0.50,0.50]
Left-Censoring Applied	16	0.48[0.00,0.75]		-
Showing Gestures	21	0.24[-0.15,0.59]	16	-0.09 [-0.62,0.48]
Left-Censoring Applied	16	0.48[0.03,0.76]		-
Imitation	23	-0.09[-0.53,0.41]	17	-0.20 [-0.66,0.39]
Left-Censoring Applied	17	-0.02[-0.60,0.53]		-
Attention Following	15	0.13[-0.40,0.62]	12	0.28 [-0.30,0.78]
Left-Censoring Applied	10	-0.13[-0.83,0.60]		-
Joint Attention Looks	24	0.23[-0.30,0.62]	18	-0.28 [-0.65,0.16]
Left-Censoring Applied	10	0.32[-0.55,0.94]	9	-0.18 [-0.89,0.58]

Note. All behaviour AoEs are right-censored, leading to different *n* values.

No significant correlations were identified between motor ability AoEs and social ability AoEs.

Correlations amongst the AoEs of the social abilities found only two significant associations: a positive correlation between the (left-censored) AoEs of joint attention looks and showing gestures, and between the (non-censored) AoEs of joint attention looks and object permanence understanding. Overall, few of the predicted potential associations were identified.

Whilst the positive correlation between joint attention look AoE and showing gesture AoE was as predicted, it must be interpreted with caution given the low sample size of the analysis. However, it does provide some preliminary indication that the assessments of joint attention looks used are potentially tapping into infants' capacity to initiate joint attention. To explore this issue further, relations between joint attention looks, showing gestures and declarative pointing gestures could be explored using a wider age range (e.g. 5 to 12 months) and larger sample size, adopting the novel methods described in Chapter 3 to examine joint attention looks. In doing so, the influence of censoring would be diminished and the presence of potential associations would become even clearer.

The significant negative correlation between the AoEs of joint attention looks and object permanence understanding was not as predicted, especially since joint attention looks emerged earlier in the majority of infants (19 out of 25; 76%). One potential explanation is that this is because those infants who were capable of joint attention looks at an earlier age were seeking to interact with E instead of engaging in the task. Those that were less likely to communicate were thus more likely to focus on the task and demonstrate object permanence understanding at an earlier age.

6.3 Conclusion

These findings provide insights into the development of a range of social, cognitive and motor developments in the key developmental period of 6 to 10 months. Analyses on the ordering of AoEs found that, at the group level, there were three broad sets of behaviours. First, it was found that despite some early social abilities emerging at around 9 months, there was still substantial variability in AoEs across infants, with some infants producing these abilities before 9 months, and infants' capacity to engage in joint attention emerging prior to 9 months. It is also important to highlight (as seen in Chapters 3, 4 and 5) that the assessed abilities often did not emerge in a consistent manner, both regarding variability in the AoEs and regarding infant performance in subsequent months after the initial emergence of abilities. Whilst this may be due to extraneous factors like infant mood and energy, it may be that there are complex, non-linear patterns of emergence in the assessed abilities. Exploring if this is the case, and if so, why, is a question for future work.

Social behaviours (assessed at the group level) emerged with a gradual trajectory: there were no social behaviours for which there was a sudden increase in the number of infants engaging in that behaviour at any point in the period of assessment. These findings call into question previous claims regarding a sudden 9-month cognitive revolution (Tomasello, 1999), instead favouring the view that social and communicative abilities emerge gradually during the first year (de Barbaro et al., 2013; Hoehl & Striano, 2013; Moll et al., 2021).

Finally, associations between different abilities were limited. Part of the issue was simply that issues of censoring made it difficult to draw strong conclusions about interrelations. The findings that were generated more closely support the view that the changes occurring at this time are unlikely to be due to a single transition in sociocognitive understanding (Carpendale & Lewis, 2004; Hoehl & Striano, 2013; Mundy & Newell, 2007).

Overall, the results align with previous work demonstrating that early joint attention and communication skills do not emerge suddenly after 9 months, but that these abilities are starting to emerge in some infants before this age, and generally in a gradual manner (de Barbaro et al., 2013, 2016; Rossmanith et al., 2014; Slaughter & McConnell, 2003; Striano & Bertin, 2005b; Striano et al., 2009). Whilst the data did not support the notion of wide-ranging relations across joint attention and communication abilities, the strength of this conclusion was reduced by the impact of censoring on the data. Future work could thus employ an even wider age range to minimise the impact of censoring and provide further insight into relations amongst early joint attention and communication abilities. Furthermore, it is clear that there are numerous benefits to developing reliable means of obtaining large-sample, high sampling frequency data about the very beginnings of the development of joint attention and communication. It is this issue the next chapter addresses.

CHAPTER 7

COMPARING MATERNAL AND RESEARCHER ASSESSMENTS OF THE BEGINNGINGS OF COMMUNICATIVE DEVELOPMENT

Thus far, the thesis has focused on infants' development solely from the perspective of the researcher. This chapter focuses on how caregivers understand communicative development, and explores how caregivers' perspectives might inform our understanding of the very beginnings of joint attention and communication in infancy.

Why is it important to draw upon caregivers' insights into early communicative development? Researchers have a grounding in the theoretical debates regarding communication and the subtleties of behavioural analysis, and thus one might choose to ignore the viewpoint of caregivers as limited and biased. Indeed, it is often suggested that caregivers tend to interpret their infant's behaviour as intentional and/or communicative at ages younger than a researcher would be willing to do so (e.g., Brady et al., 2012). However, there are both practical and theoretical motivations for drawing upon caregiver insights into communicative development.

Practically, developing effective tools for obtaining caregiver reports of infant behaviour has numerous benefits. Completing a questionnaire, interview or diary is procedurally simpler, shorter and cheaper than collecting video recordings of free play interactions or experimental procedures (Eadie et al., 2010; Sachse & Von Suchodoletz, 2008). The infant does not need to be present, simplifying the ethical process and removing the factors of infant energy or mood (Nordahl-Hansen et al., 2014). This allows for a simpler recruitment process, larger sample sizes, and more regular sampling frequency. Moreover, caregivers observe the infant in the natural contexts of their daily life, with familiar environments and people (Adolph et al., 2008). They also spend far more time with the infant than any researcher could, meaning they have an enormous number of opportunities to observe key behaviours. This means they have the opportunity to notice subtle changes and developments that may be missed by researchers, who cannot feasibly observe infants at such regular intervals. Caregivers also have the opportunity to capture the very beginnings of behaviours that may only occur infrequently, especially as they are just starting to emerge (Ellis-Davies et al., 2012).

Theoretical motivation for drawing upon caregiver reports of communicative development can be found from work on the "second-person perspective" in social understanding and development (Gallagher, 2001; Gómez, 1996; Moore & Barresi, 2017; Reddy, 1996, 2010; Schilbach et al., 2013; Siposova & Carpenter, 2019). The common point of agreement amongst second-person approaches is that research into human social understanding must examine how this understanding manifests within the context of second-person, interactive engagements, as opposed to (solely or primarily) disengaged third-person social observation. From a second-person theoretical perspective, caregivers have a unique kind of epistemic insight into the meaning of their infant's communicative behaviours (Reddy & Trevarthen, 2004). From this theoretical standpoint, dichotomising caregiver assessments as subjective and researcher assessments as objective fails to recognise the unique insights afforded to caregivers, insights that can be leveraged to contribute to the broader goal of understanding infants' communicative development.

Previous work on the development of joint attention and communication has drawn upon caregiver reports. Caregiver questionnaires have been developed that use checklists of different behaviours (e.g. gestures, language production and comprehension) to record infants' communicative developments (e.g. the MacArthur-Bates Communicative Development Inventories (CDI; Fenson et al., 1994), the Communication and Symbolic Behavior Scales Developmental Profile (CSBS DP) Caregiver Questionnaire (Eadie et al., 2010; Wetherby & Prizant, 2003)). However, for practical reasons, these checklists cover a range of communicative behaviours in a brief manner in order to obtain scores or totals that give a broad sense of infants' communicative capacities, rather than offering a detailed exploration of specific communicative abilities. Furthermore, these questionnaires have generally focused particularly on language development. Other studies have used diary methods to obtain detailed caregiver perspectives on pre-linguistic communication, investigating topics such as the development of giving gestures (Carpendale et al., 2021) and pointing gestures (Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018). This approach provides, rich, detailed data, with high sampling frequency, allowing insights into the variability of infants' behaviour and the activity of caregiver-infant dyads. However, a limitation of these methods is that it is difficult to generalise the results more widely, given the typically low number of participants.

An issue underlying both checklist and diary methods is how caregiver reports relate to researcher assessments. Even when acknowledging the practical and theoretical benefits of caregiver reports, it is important to have clarity regarding how caregivers report communicative behaviours and whether they do so in a comparable manner to researchers. No previous work has directly compared caregivers reports' of infants' early communicative development with researcher assessments of those same infants, and the majority of previous studies that have examined communicative development in older infants are not longitudinal. This study aims to address both of these issues.

Previous studies have suggested that the degree of similarity between caregiver and researcher assessments depends on the type of skill assessed. For example, caregiver reporting of motor skills, both gross (e.g. sitting, standing) and fine (e.g. manual control), is generally reliably similar to researchers' assessments (Bodnarchuk & Eaton, 2004; Libertus & Landa, 2013; Miller et al., 2017). A similar pattern can be identified in caregiver reports of language development. Prior research has found that caregivers can generally accurately record language development, with multiple effective assessment tools available (Feldman et al., 2005; Nordahl-Hansen et al., 2014; Sachse & Von Suchodoletz, 2008). For example, the CDI has been repeatedly shown to be a valid measure of language development across a range of ages (Fenson et al., 1994; Heilmann et al., 2005; Law & Roy, 2008; Mayor & Mani, 2019).

Whilst caregiver reports have generally proved reliable and useful in these domains, there is much greater variability and complexity in assessments of caregiver judgements of infant intentionality (Bauer & Twentyman, 1985; Feldman & Reznick, 1996; Reznick & Schwartz, 2001; Zeedyk, 1994). Following Feldman and Reznick's (1996) broad definition, intentional actions involve some goal being deliberately executed. However, researchers do not agree on the conditions under which infant behaviour can be considered intentional (Barresi & Moore, 1996; Delafield-Butt & Gangopadhyay, 2013; Reznick & Schwartz, 2001; Vedeler, 1987; Zeedyk, 1996). It is therefore little surprise that obtaining caregiver judgements of intentionality has proved challenging: if there is little agreement over what constitutes intentional action, there is likely to be a lack of consistency in caregiver (or, indeed, researcher) assessments.

Whilst this issue is clearly relevant to intentional communication (being a form of intentional action), previous work has suggested that, at least broadly, the task of identifying intentional communication is one in which non-expert adults are competent. Adamson and colleagues (1987) asked adults (both caregivers and non-caregivers) who were asked to watch recorded interaction between mothers and infants at 9, 15 and 21 months of age, and highlight instances of intentional communication. They used a broad definition, asking the adults to press a button "whenever the baby seems to be trying to communicate… each time you think the baby was trying to convey some meaning" (p. 384). Both caregivers and non-caregivers were broadly consistent in their identification of intentionally communicative acts during the interactions, particularly with the older infants.

Whilst this study implies a broad capacity to identify intentionally communicative acts, it does not focus on the differing challenges of different forms of communicative behaviour. Focusing on more specific communicative behaviours (including gestures, vocalisations, eye contact and emotional expressions), Eadie and colleagues (2010), suggested that the more clearly identifiable nature of gestures relative to other early communicative abilities means they can be more consistently identified by caregivers, relative to researcher assessments. Similarly, Reznick and Schwartz (2001), in their study comparing caregiver judgements of intentionality and judgements of language, suggested that the "salient, familiar and easily observable" (p. 11) nature of linguistic utterances makes it easier for caregivers to provide more consistent and reliable assessments of language relative to judgements of intentionality. This insight is also relevant to the relative assessment of intentionally communicative behaviours by caregivers and researchers: for behaviours with clearer, more commonly identifiable features, there is likely to be more consistency in identification.

This point also pertains to assessments of behavioural emergence: if behaviours cannot be consistently identified, the reporting of ages of emergence (AoEs) will likely differ. However, quite how they differ is not clear, and there are different plausible predictions regarding caregivers' assessments of the emergence of communicative abilities. First, it is possible that caregivers are more likely to credit their infants with being capable of communicative abilities, and reported earlier AoEs for communicative behaviours. It has been suggested that caregivers are predisposed to apply more minimal criteria than researchers when questioned about their infant's capabilities. For example, Tomasello and Mervis (1994) suggested that in the context of word comprehension, caregivers might interpret questions regarding word understanding (e.g. “Does your child know the word ‘ball’?”) as a question about their infant’s general familiarity with that object (i.e., “Does your child understand what a ball is, even though he or she does not say its name?”; p. 177). Whilst researchers have specific definitions of various communicative abilities, their interpretations may differ from caregivers. For example, researchers will often restrict “pointing” to communicative, distal pointing, rather than behaviours like index-finger exploration and pointing-for-self. These differing criteria will often lead to caregivers providing earlier identification of behaviours (Tomasello & Mervis, 1994). A further reason why caregivers may identify communicative behaviours earlier is simply because they have far more opportunities to notice these behaviours, and to thus catch these abilities just as they emerge (Adolph et al., 2008; Ellis-Davies et al., 2012).

Alternatively, it may be the case that caregivers are not always more likely to credit their infant with being capable of communicative behaviours, and do not consistently assess communicative behaviours as emerging earlier than researchers. For behaviours that involve relatively straightforward and common criteria of assessment, it is likely that assessments are similar. This may account for the broad similarity of caregiver and researcher assessments of abilities like motor skills (Bodnarchuk & Eaton, 2004; Libertus & Landa, 2013; Miller et al., 2017), language (Fenson et al., 1994; Mayor & Mani, 2019), and gestures (Eadie et al., 2010). However, for less clear behaviours, it is plausible that caregivers are more generous in their interpretations than researchers (Tomasello & Mervis, 1994). However, an alternate possibility is that caregivers in fact become more conservative, requiring more examples or clearer behaviours in order to assess their child as being capable of a particularly ability (Zeedyk, 1997).

In summary, it is not clear how caregivers assess the very beginnings of communicative development relative to researchers. Previous studies (e.g. Eadie et al., 2010;

Fenson et al., 1994) have obtained general reports of a variety of behaviours, rather than focusing on a reduced set of behaviours in more detail. Additionally, maternal assessments of communicative behaviours have not been directly compared to researcher assessments of the same infants, whether at a single point in time or longitudinally. This study aimed to address this gap by examining a cohort of infants over time and assessing both maternal and researcher interpretations of communicative development at each time point.

The overall aims of this study were 1) to examine maternal assessments of infants' early communicative behaviours and 2) to compare how these assessments relate to researcher assessments of the same behaviours. Regarding the first aim, this study provided data on maternal assessments of the beginnings of communicative development through monthly semi-structured interviews. Whilst semi-structured interview methods are diverse (McIntosh & Morse, 2015), they generally combine set questions with the opportunity for follow-up questions by the researcher and elaboration by participants. The interview method was adopted in order to provide detailed information that enabled greater clarity regarding what mothers believed their infant was capable of doing, allowing mothers to justify and elaborate on their reports.

The study focused on two of the earliest communicative abilities: joint attention looks and showing gestures. These behaviours are critical to our understanding of the origins of infants' communication, but differ in terms of their familiarity and use in common discourse. Previous work has suggested that caregivers are capable of identifying communicative gestures more easily than other communicative behaviours such as eye-contact and vocalisations (Eadie et al., 2010). Furthermore, mothers are not typically familiar with the concept of "joint attention" (Salter et al., 2021), and do not reliably identify "sharing looks" (using the assessment criteria of Hobson and Hobson (2007)) when observing interactions as a third party (Graham et al., 2021). Thus, whilst both showing gestures and joint attention looks are communicative, it is plausible that they pose different challenges when it comes to the relative assessments of mothers and researchers.

Regarding the second aim, the study sought to assess the relation between maternal assessments of early communicative behaviours and researcher assessments of these behaviours, to examine whether mothers assess the emergence of these behaviours and their production over time differently to researchers. As a point of comparison, beliefs about two gross motor developments, independent sitting and self-locomotion, were also included. It was predicted that these would represent behaviours that are clear and salient to mothers and researchers alike (Reznick & Schwartz, 2001). Furthermore, mothers received the UK version of the CDI (UK-CDI; Alcock et al., 2020) at 8 months, in order to examine whether there was any difference in reporting when mothers were provided with a single question regarding showing gesture production rather than describing their infants' behaviour in a semi-structured interview.

In light of previous studies, it was predicted that mothers would assess motor skills in a manner similar to the researchers, not reporting these skills as emerging earlier and reporting similar numbers of infants producing these behaviours to researchers. It was predicted that maternal assessments of showing gesture AoE and development (from both interviews and the UK-CDI) would be similar to researcher assessments, given previous evidence that the criteria used to assess this behaviour is somewhat consistent across caregivers and researchers (Eadie et al., 2010). For assessments of joint attention looks, it was predicted that there would be differences between maternal and researcher assessments of joint attention look AoE and development. However, the direction of these differences could be in either direction. On the one hand, following Tomasello and Mervis (1994), mothers could be prone to identify joint attention looks earlier by applying minimal criteria. On the other hand, it is possible that mothers would identify joint attention looks later than researchers, due to a lack of clear criteria for identifying infants' capacity to produce joint attention looks.

7.1 Method

Maternal interviews and researcher assessments were conducted each month from 6 to 10 months, whilst the UK-CDI was collected at 8 months.

7.1.1 Procedure

The use of a semi-structured interview allowed for detailed data from which maternal assessments could be identified. The researcher was able to ask follow-up questions and clarify responses, whilst the mothers were able to elaborate on their responses if they wished. However, direct questions that could overly bias participant responses were avoided. The approach taken for each behaviour type is detailed in the following sections. Details of the interview set-up can be found in Chapter 2 (section 2.3.6). The interview also included several further questions that are not discussed here. The full list of questions can be found in Appendix 7A.

7.1.1.1 Gross Motor Abilities

Chapter 5 (section 5.3) contains the details of the procedures and coding strategy for independent sitting and self-locomotion.

To assess whether the mother believed her infant was capable of independent sitting, mothers were asked, "Can your infant sit by him/herself? If so, for how long?"

To assess whether the mother believed her infant was capable of self-locomotion, mothers were asked, "Does your infant move him/herself around? If so, how?" This phrasing was chosen as infants capable of self-locomotion do so in a variety of ways, and it was expected that self-locomotion would not be a familiar phrase.

7.1.1.2 Joint Attention Looks

Chapter 3 (section 3.1) contains the details of the experimental procedures and researcher coding strategy for joint attention looks. The researcher assessments here drew upon the combined joint attention looks scores across the various assessment tasks outlined in Chapter 3, which included three elicitation procedures and the free play period.

The questions relating to the infant's looking behaviour were as follows:

"Have there been any changes in how often your infant is looking at you?"

"In what contexts or situations does your infant look at you?"

"How does your infant react to interesting things?"

"How does your infant react to surprising or scary situations?"

However, coding of the interviews was not limited to these questions, since relevant responses were sometimes found in response to other questions. For example, relevant responses were often provided in response to the question "Does your infant show you interesting toys or objects?", or emerged organically out of discussions of other questions.

To try to explore maternal understanding in depth, several follow-up questions were used to encourage elaboration. The overall purpose of these questions was to try to navigate the delicate balance between avoiding leading questions and seeking to ascertain the mothers' beliefs about her infant's looking behaviour. Thus, the follow-up questions used increased in specificity regarding the potential communicative nature of the infants' looking behaviour.

"How would you describe how your infant looked at you?"

"Why do you think your infant was looking at you?"

"Was your infant looking at you to check you were there, or for some other reason?"

"Was your infant trying to tell you something?"

The researcher also encouraged elaboration by asking, "What makes you think that you infant is doing that?" or some similar phrasing. This encouraged mothers to elaborate on the various kinds of evidence they used to arrive at their belief.

7.1.1.3 Showing Gestures

Chapter 4 (section 4.1.3) contains the details of the procedures and researcher's coding strategy for showing gestures. The researcher assessments here drew upon the combined showing scores across the various assessment tasks outlined in section 4.3, which included two elicitation procedures and the free play period.

Two main questions were asked that addressed infants' ability to produce showing gestures:

1. Does you infant produce any gestures? If so, what kind of gestures?
2. Does your infant show you interesting objects? If so, how do they do this?

In some cases, the mother mimed the relevant motion, and this mime was described within the transcription. As with joint attention looks, a further follow-up question was, "What makes you think that your infant is showing you the object?", or another similar phrasing.

At 8 months, mothers completed the UK-CDI. One of the questions related to production of showing gestures. The exact phrasing was:

"When infants are learning to communicate they often use gestures to get a message across. For each of the gestures below, please mark the actions that you have seen your child do… Extends an arm to show you something she or he is holding."

7.1.2 Behavioural Coding

Each semi-structured interview was transcribed in full, and a three-level coding scheme was employed to code responses. The CDI has a separate scoring system, which is discussed in section 7.1.2.3. This coding strategy was designed to be analogous to the researcher coding schemes that were applied. Just as the mothers' responses were coded in terms of certainty, so the researcher assessments of infants' capabilities were on a scale of certainly capable, possibly or somewhat capable and incapable. Thus, the conceptual structure of each was such that a direct comparison of scores was appropriate. The conceptual structure of the scheme is outlined in Table 7.11

Table 7.1

Behavioural Coding Scheme Structure for Maternal Assessments

Score	Description
2	The mother is sure that the infant is capable of the target behaviour.
1	The mother believes the infant might be capable, or is capable in some limited capacity of the target behaviour.
0	The mother is sure that the infant is not capable of the target behaviour.

For coding of the maternal responses, the language used by the mother was assessed on its certainty or confidence. Coders noted whether the mother had hesitations, alternative explanations, or changed her mind as she provided her response, or whether she was clearly confident in her identification of a target behaviour. Whilst confident maternal responses were taken at face value for the purpose of coding, it did have to be clear that the specific behaviour of interest was what the mother was referring to. Thus, various minimal criteria were specified in each case to rule out any significant misunderstandings or different uses of the terms under consideration. Besides these minimal cases (listed in the subsequent sub-sections), no further criteria were specified for each behaviour type. The full coding schemes can be found in Appendix 7B.

7.1.2.1 Gross Motor Abilities

For a score of “2” for independent sitting, the mother had to report that the infant was able to sit independently, without external support (i.e., by a caregiver or support seat). This was to rule out cases in which the mother was confident the infant was able to sit on a lap or in an infant chair. Furthermore, the researcher coding scheme had set 10 seconds as the threshold for independent sitting (Rachwani et al., 2017), to be confident that the infant could genuinely sit without support. Similarly, it was decided that, to receive a score of “2”, mothers also had to report that the infant was capable of independent sitting for some extended period of approximately 10 seconds or more. This was achieved using either explicit time judgements (e.g. “for about 30 seconds”) to ascertain if this was over 10 seconds, or using other clear indications such as “for a long time” or “as long as he/she wants”. For a score of “1”, mothers had to believe their infant was capable of some limited period of independent sitting, and a score of “0” was assigned if mothers did not believe the infant was capable of independent sitting.

For a score of “2” for self-locomotion, the mother had to report that the infant was capable of self-locomoting consistently to get to a desired location. Because the researcher coding scheme ruled out rolling, this was also ruled out from mothers' responses. The researcher coding scheme had set a threshold of a minimal distance of two body lengths (Walle, 2016), to be confident that the infant could genuinely self-locomote. Similarly, it was decided that, for a score of "2", mothers had to report that the infant was capable of moving some substantial distance, such as "a long distance" or "can get where they want to go". For a score of "1", mothers had to believe their infant was capable of some limited self-locomotion (not including rolling). For example, if the mother stated that the infant "could crawl a little" or "was just starting to move herself forward", a score of "1" was assigned. For a score of "0", mothers had to believe the infant was not capable of self-locomotion.

7.1.2.2 Joint Attention Looks

For a score of "2" for joint attention looks, the mother had to report that her infant intentionally looked to others (mother, caregiver or other person) in order to communicate about or comment on some stimulus. It had to be clear that this communication was about some stimulus, rather than a more generic sense of communication (e.g. "I'm hungry"). However, beyond this requirement, no further criteria were stipulated regarding the precise description of the behaviours involved, even if there were indications that the criteria being used to assess joint attention looks differed from the criteria applied by researchers. A score of "1" was assigned if the mother reported that the infant possibly produced joint attention looks, but was not certain of this. If the mother reported the infant intentionally looked to her in response to some stimulus, but it was not clear that it was communicative, a score of "1" was assigned. For example, the mother might state "maybe he's saying 'Look at this!'" or, "she looks to me, but I'm not sure why". A score of "0" was assigned if the mother did not report that her infant intentionally looked to a person in response to some stimulus, or communicated about some stimulus using looking behaviour.

7.1.2.3 Showing Gestures

For a score of “2” for showing gestures, the mother had to report that the infant was gesturally showing objects. Mothers had to refer to gestural showing specifically; if looking behaviour alone was described as “showing”, these cases did not receive a score of “2”. Besides these, no further criteria were stipulated regarding the precise description of the behaviours involved. A score of “1” was assigned if the mother reported that the infant was possibly producing showing gestures, for example by saying “I think she might be holding up objects to show me.” A score of “1” was also assigned if the mother was capable of showing gestures in some limited capacity, for example by stating “he shows me objects but not in a very controlled way.” A score of “0” was assigned if the mother did not believe her infant to be capable of producing showing gestures, or any relevant behaviours related to showing gestures.

The CDI uses a three-level scoring system, but the meaning of each score is different to the three-level scheme applied in this study, with “0” meaning “never”, “1” meaning “sometimes” and “2” meaning “often.” Thus, “1” and “2” CDI scores were collapsed to provide “absent” (“0”) or “present” (“1” or “2”) scores (with the logic being that “sometimes” judgements implied that mothers believed the infant was capable of that behaviour, even if infrequently). For the purposes of comparison with maternal interview assessments and researcher assessments, dichotomous present versus absent scores were used (though for the researcher coding, scores of “1” counted as “absent” given the nature of “1” scores in those schemes). Reliability for each of these scores can be found in Appendix 2B.

7.1.3 Analyses

The first set of analyses focus on the relative reporting of the AoEs of the assessed skills. To examine whether either mothers or researchers consistently reported the emergence of different skills at an earlier age, binomial tests were used. Because of widespread issues of both left and right censoring, this approach was taken rather than direct comparisons between AoEs (see Beuker et al., 2013, for a similar approach). Two sets of tests were conducted. The first collapsed the "researcher AoE assessment earlier" and "equivalent AoE assessments" scores, in order to examine whether the proportion of cases in which the maternal AoE assessments were earlier than the researcher AoE assessments differed from chance. The second collapsed the "maternal AoE assessment earlier" and "equivalent AoE assessments" scores, in order to examine whether the proportion of cases in which the researcher AoE assessments were earlier than the maternal AoE differed from chance.

The second set of analyses examine the respective reporting of confident assessments of each behaviour (i.e., scores of "2"). GLMMs were specified to examine whether there were significant differences between scores at each month. Because of the complex model structure required to assess these differences, and because at some months had 0% or 100% of participants receive a score, some of the analyses focus on the key subset of months rather than all five, to ensure the models only focus on the key months of interest for each skill whilst maintaining a model that did not assume independence of measures. For each model, the dependent variable was binary outcome indicating whether the skill in question was produced ("0" for skill not produced, "1" for skill produced). Participant was entered as a random effect, and an interaction between age and assessor (mother or researcher) was entered. The models used a binomial error structure and logit link function. The tables of coefficients can be found in Appendix 7C.

Finally, to examine differences in the population-level reporting of “0”, “1” and “2” scores are assessed by calculating Cohen’s Kappa coefficient (with squared weighting) and percentage agreement between maternal and researcher assessments.

7.2 Results

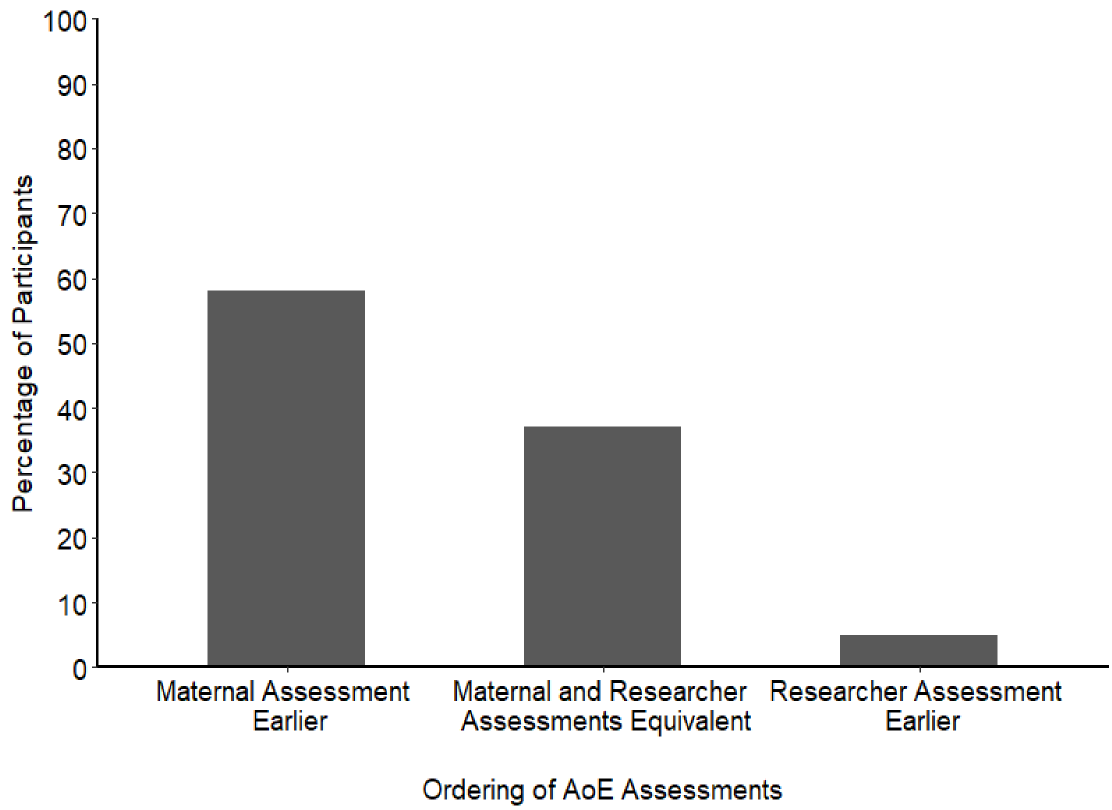
7.2.1 Gross Motor Abilities

7.2.1.1 Independent Sitting

Figure 7.1 shows the percentages of cases in which maternal and researcher assessments of independent sitting AoE were different or equivalent.

Figure 7.1

Orderings of Experimental and Maternal Assessments of Self-Locomotion Emergence

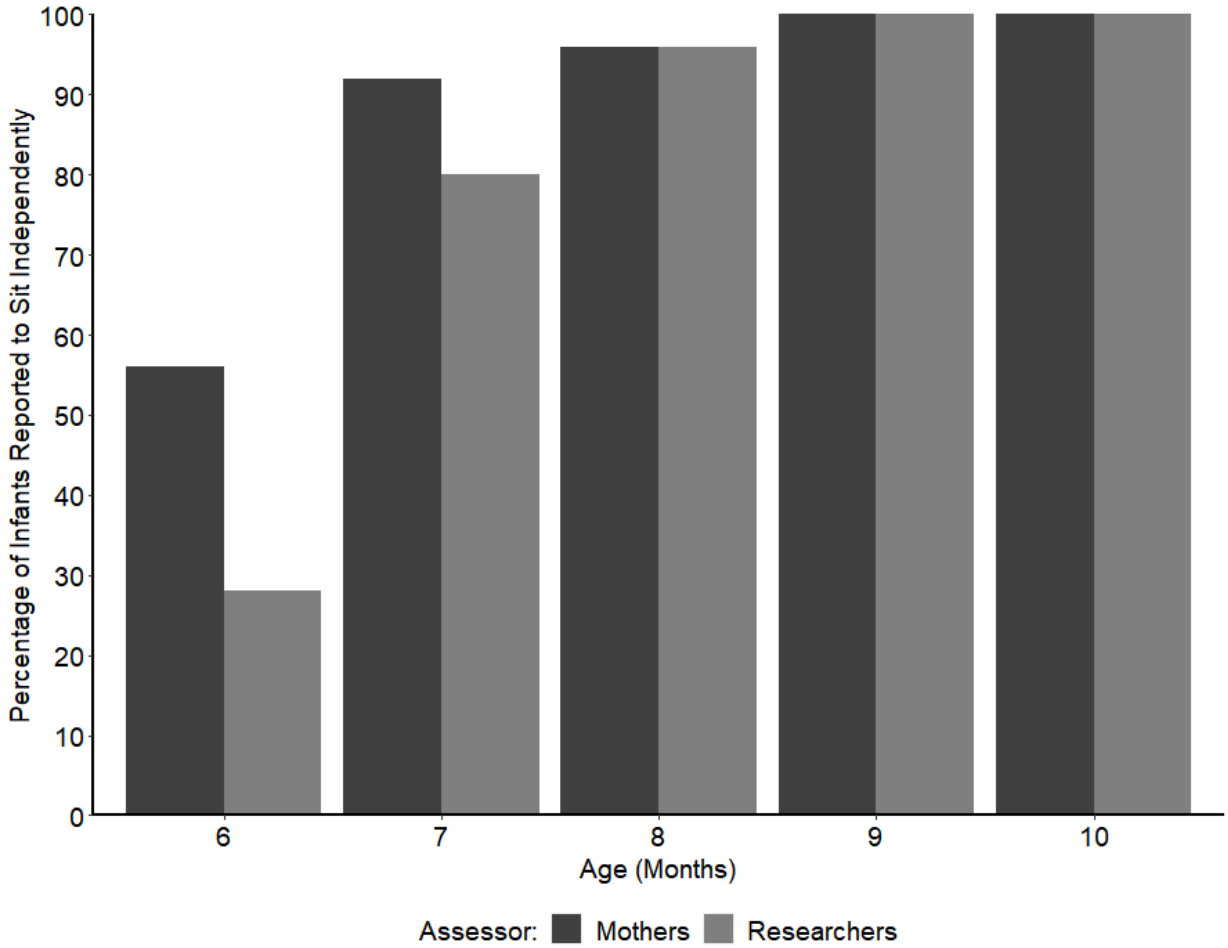


Excluding cases in which censoring made the ordering uncertain, it was found that in 11 out of 19 cases (58%) the maternal AoEs were earlier, in 7 out of 19 (37%) cases the AoEs were equal and in 1 out of 19 (5%) cases the researcher AoE was earlier. The proportion of cases in which mothers reported independent sitting earlier than researchers was not significantly different from chance (two-tailed binomial test, $p = 0.65$, 95% CI [0.33, 0.80]), and the proportion of cases in which researchers reported independent sitting earlier than mothers was different from chance (two-tailed binomial test, $p < 0.001$, 95% CI [0.00, 0.26]). Overall, these results indicate that neither mothers nor researchers consistently reported the AoE of independent sitting at an earlier age.

The next set of analyses examined differences between mothers' and researchers' scores at each month. Figure 7.2 displays the percentage of infants who were assessed to be capable of independent sitting (scores of "2") by mothers and by researchers, respectively.

Figure 7.2

Percentage of Infants who Received an Independent Sitting Score of "2" at each Month, Comparing Maternal and Researcher Assessments



To compare mothers' and researchers' assessments, a GLMM was specified. Because all infants were recorded as capable of independent sitting by both mothers and researchers at 9 and 10 months, and because scores were identical at 8 months, the fitted model only examined scores at 6 and 7 months to avoid an imbalanced model. A Tukey's HSD post hoc test based on assessor conditioned by age found a significant difference in the number of infants reported to be capable of independent sitting at 6 months (z = -2.06, p = 0.04). These results indicate that mothers were more likely to report independent sitting as this ability was starting to emerge (at 6 months) but not at later ages (7 months and older).

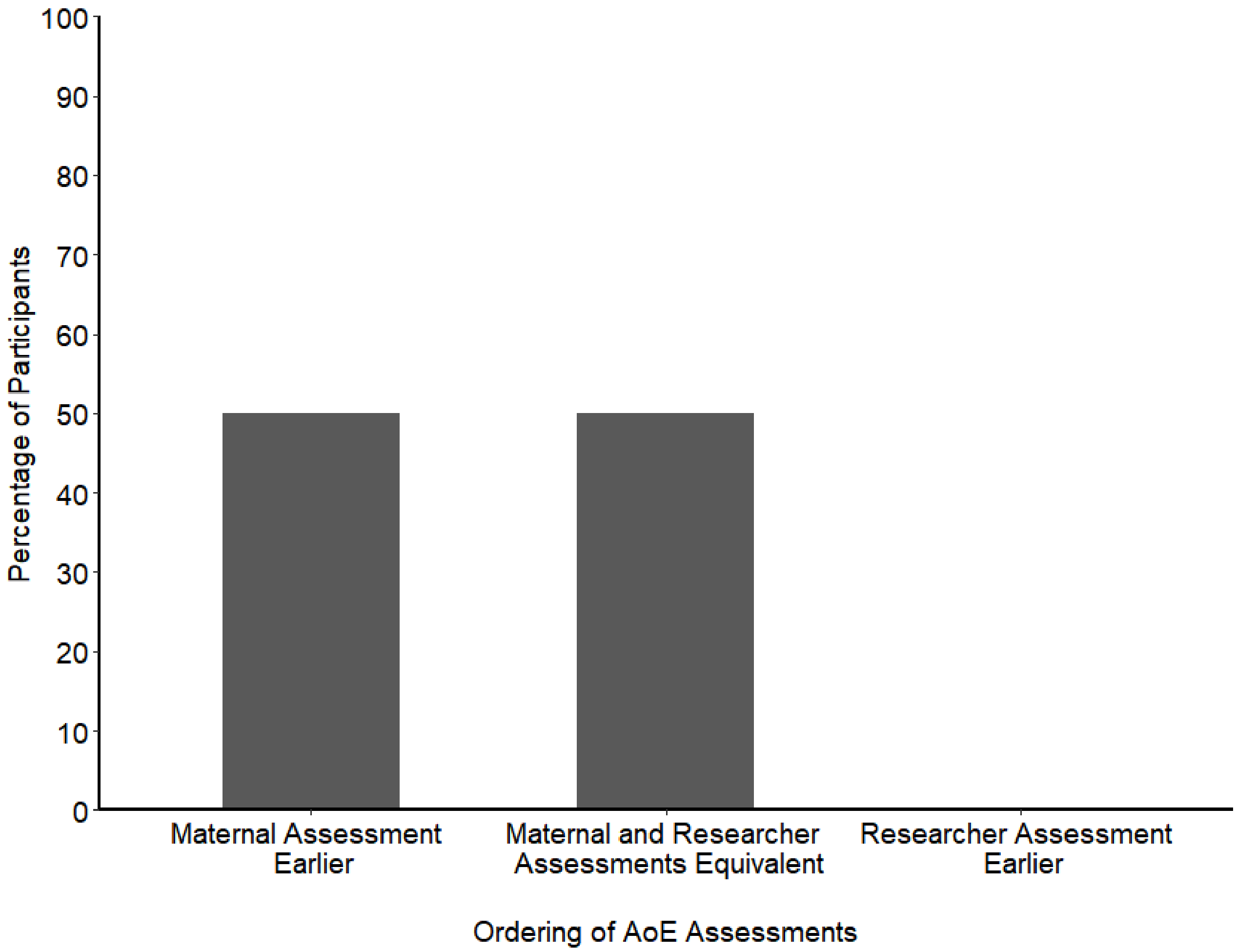
The final analysis investigated the overall consistency between mothers' and researchers' assessments of scores of "0", "1" and "2" for independent sitting. Percentage agreement was 84.7% and Cohen's Kappa coefficient was 0.52κ, suggesting moderate agreement between the scores assigned by mothers as a group and the researchers.

7.2.1.2 Self-Locomotion

Figure 7.3 shows the percentages of cases in which maternal and researcher assessments of self-locomotion AoE were different or equivalent.

Figure 7.3

Orderings of Experimental and Maternal Assessments of Self-Locomotion Emergence

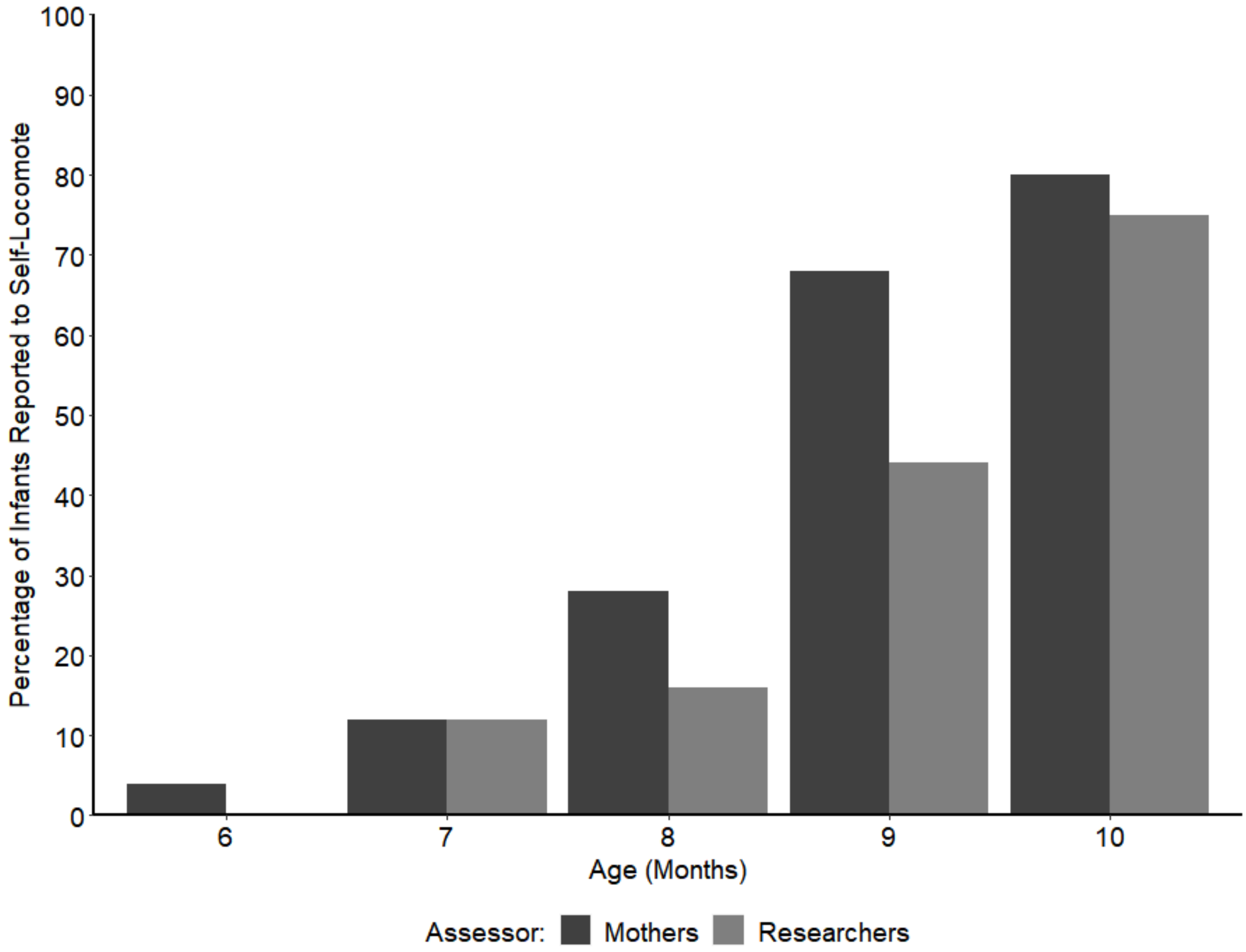


Excluding cases where censoring made the ordering uncertain (as both AoE assessments were at 6 months), it was found that in 9 out of 18 (50%) cases the maternal AoEs were earlier, in 9 out of 18 (50%) cases the AoEs were equal and in no cases were the researcher AoEs earlier. The proportion of cases in which mothers reported independent sitting earlier than researchers was not significantly different from chance (two-tailed binomial test, $p = 1.0$, 95% CI [0.26, 0.74]), and the proportion of cases in which researchers reported self-locomotion earlier than mothers was significantly different from chance (two-tailed binomial test, $p < 0.001$, 95% CI [0.00, 0.19]). Overall, these results indicate that neither mothers nor researchers consistently reported the AoE of self-locomotion at an earlier age.

Figure 7.4 displays shows the percentage of infants who were assessed to be capable of self-locomotion (scores of “2”) by mothers and by researchers.

Figure 7.4

Percentage of Participants who Received a Self-Locomotion Score of “2” at each Month, Comparing Maternal and Researcher Assessments



To compare relative assessments of self-locomotion ability, a GLMM was specified. Because there was only one participant who received different assessments at 6 months, and because scores were identical at 7 months, the fitted model only examined scores at 8, 9 and

10 months to avoid an imbalanced model. A Tukey's HSD post hoc test based on assessment type conditioned by age found significant differences in the number of infants reported to be capable of self-locomotion at 8 ($z = -2.82$, $p = 0.005$) and 9 ($z = -4.49$, $p < 0.001$) months. These results indicate that mothers were more likely to report self-locomotion as this ability was starting to emerge (between 8 and 9 months) but not at 10 months.

The final analysis investigated the overall consistency between mothers' and researchers' assessments of scores of "0", "1" and "2" for self-locomotion. Percentage agreement was 74.2% and Cohen's Kappa coefficient was 0.78κ, suggesting good agreement between mothers as a group and the researchers.

7.2.1.3 Discussion

Overall, the results are in line with previous research suggesting that maternal and researcher assessments of motor milestones are broadly similar, though with some important differences. The results for independent sitting indicated a difference between earlier assessments of independent sitting, at 6 months. Given full agreement at 9 and 10 months, this suggests that there were disagreements in the earlier months, when independent sitting was just starting to emerge. In half of the cases the reported AoEs were identical, and in half the mothers reporting sitting earlier, though it is worth noting that a conservative approach was taken to censoring, meaning 7 equivalent AoE assessments were removed (which may have genuinely been equivalent). There was moderate reliability (0.52κ) and high percentage agreement (84.7%). Overall, there were some differences regarding the very beginnings of independent sitting, but with overall similar scores in the period of assessment. Whilst this may be due to less restrictive criteria being applied by mothers, it is also possible that the approach to coding independent sitting from the lab sessions was limited, as there was no direct test of infant sitting capabilities, meaning that in some cases sitting might not have been witnessed even though the infant was capable of doing so.

For self-locomotion, there was a similar pattern, with overall similar scores but differences at the months in which the behaviour starting to emerge in the population. When the scores of "2" were examined, differences were identified, again in the months (8 and 9) when self-locomotion was emerging amongst a large proportion of infants. For assessments of AoEs, there was no significant proportion of either mothers or researchers that reported the emergence of self-locomotion earlier. Additionally, there was strong reliability (0.78κ) and good agreement (74.2%), suggesting overall similar scores. However, despite some differences, assessments of self-locomotion between mothers and researchers were broadly similar.

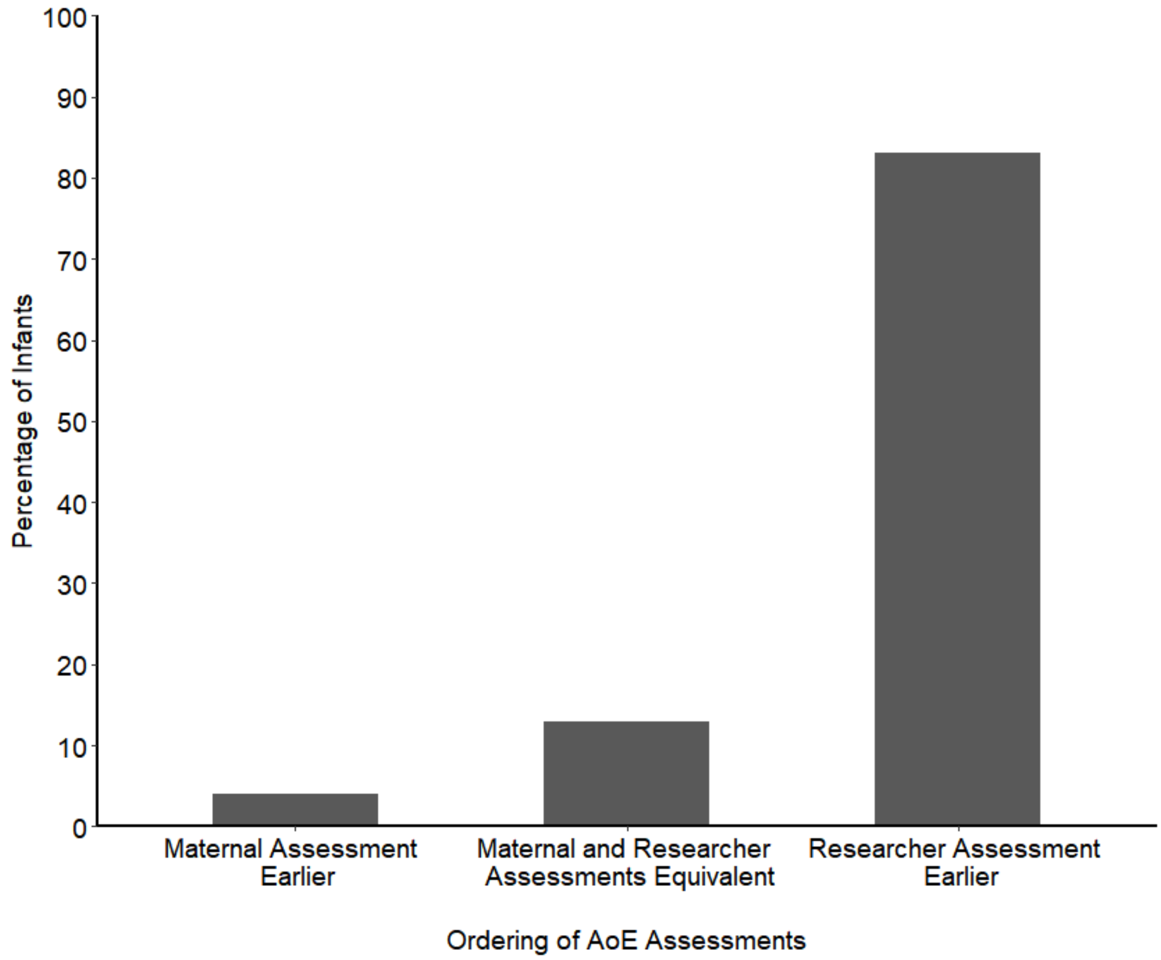
Overall, the results are broadly in line with previous claims (Bodnarchuk & Eaton, 2004; Brandone, et al., 2020; Miller et al., 2017). Whilst reports of gross motor developments were generally similar between mothers and researchers, there were some points of difference, particularly in the periods where the abilities were just beginning to emerge.

7.2.2 Joint Attention Looks

The next analyses focused on the relative reporting of joint attention look AoE. Figure 7.5 shows the percentages of cases in which maternal and researcher assessments of joint attention look AoE were different or equivalent.

Figure 7.5

Orderings of Experimental and Maternal Assessments of Joint Attention Look Emergence

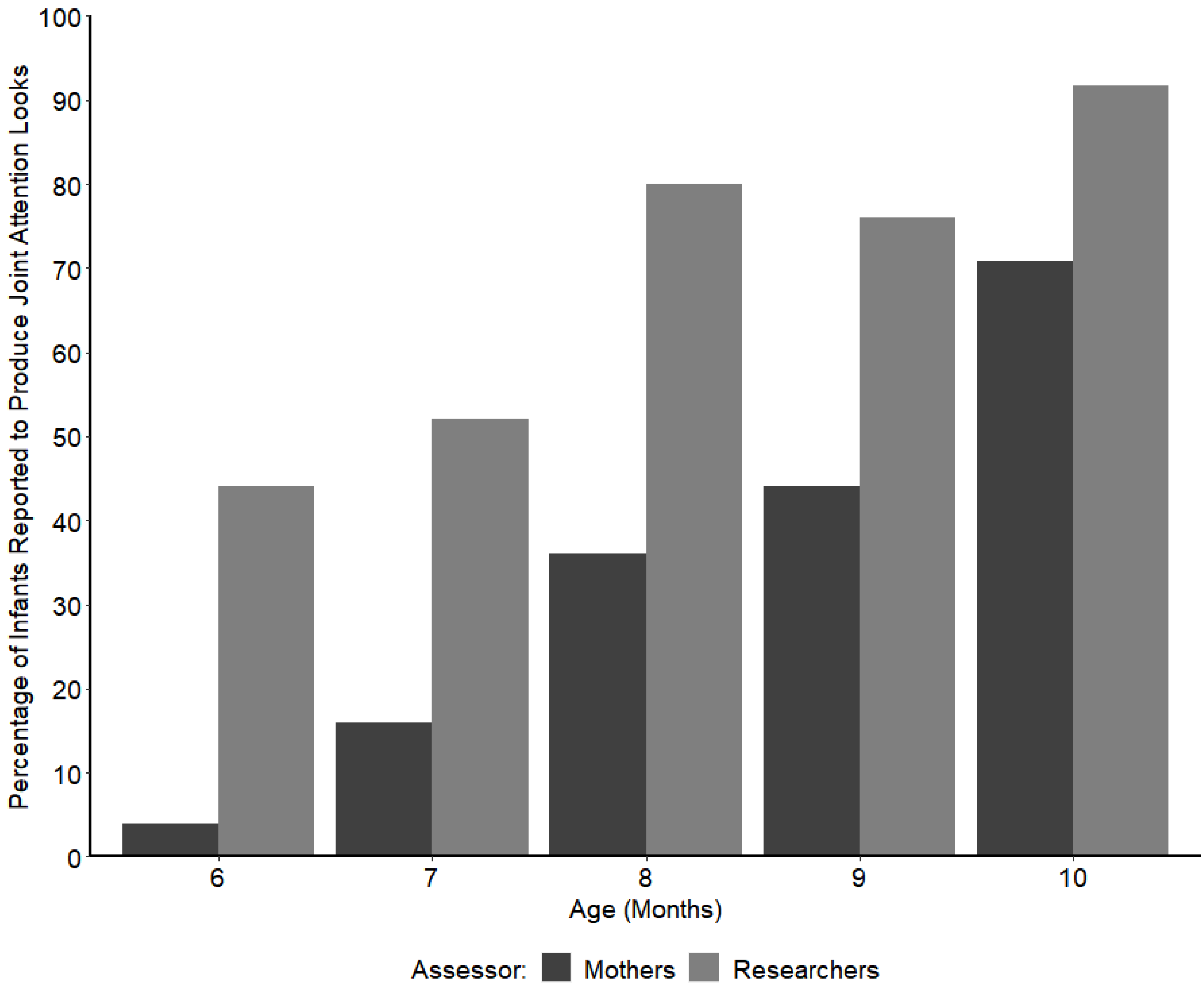


Excluding cases where censoring made the ordering uncertain, it was found that in 1 out of 24 (4%) cases the maternal AoEs were earlier, in 3 out of 24 (13%) cases the AoEs were equal and in 20 out of 24 (83%) cases the researcher AoEs were earlier. The proportion of cases in which mothers reported independent sitting earlier than researchers was significantly less than chance (two-tailed binomial test, $p < 0.001$, 95% CI [0.00, 0.21]), and the proportion of cases in which researchers reported independent sitting earlier than mothers was significantly greater than chance (two-tailed binomial test, $p = 0.002$, 95% CI [0.63, 0.95]). These results indicate that the researchers typically identified the onset of joint attention looks at an earlier age than mothers did.

Figure 7.6 displays shows the percentage of infants who were assessed to be capable of joint attention looks (scores of "2") by mothers and by researchers.

Figure 7.6

Percentage of Participants who Received a Joint Attention Look Score of "2" at each Month, Comparing Maternal and Researcher Assessments



To compare relative assessments of pass rates, a GLMM was specified. A Tukey's HSD post hoc test based on assessment type conditioned by age found significant differences in the number of infants reported to be producing joint attention looks at 6 (z = 2.82, p =

0.005), 7 ($z = 2.71$, $p = 0.007$), 8 ($z = 3.42$, $p = 0.001$) and 9 ($z = 2.66$, $p = 0.016$) months. These results indicate that assessments of joint attention looks by mothers and researchers were dissimilar until the infants were 10 months old, at which point assessments were not significantly different.

The final analysis examined the overall consistency between mothers' and researchers' assessments of scores of "0", "1" and "2" for joint attention looks. Percentage agreement was 42.7% and Cohen's Kappa coefficient was 0.12κ, suggesting low agreement.

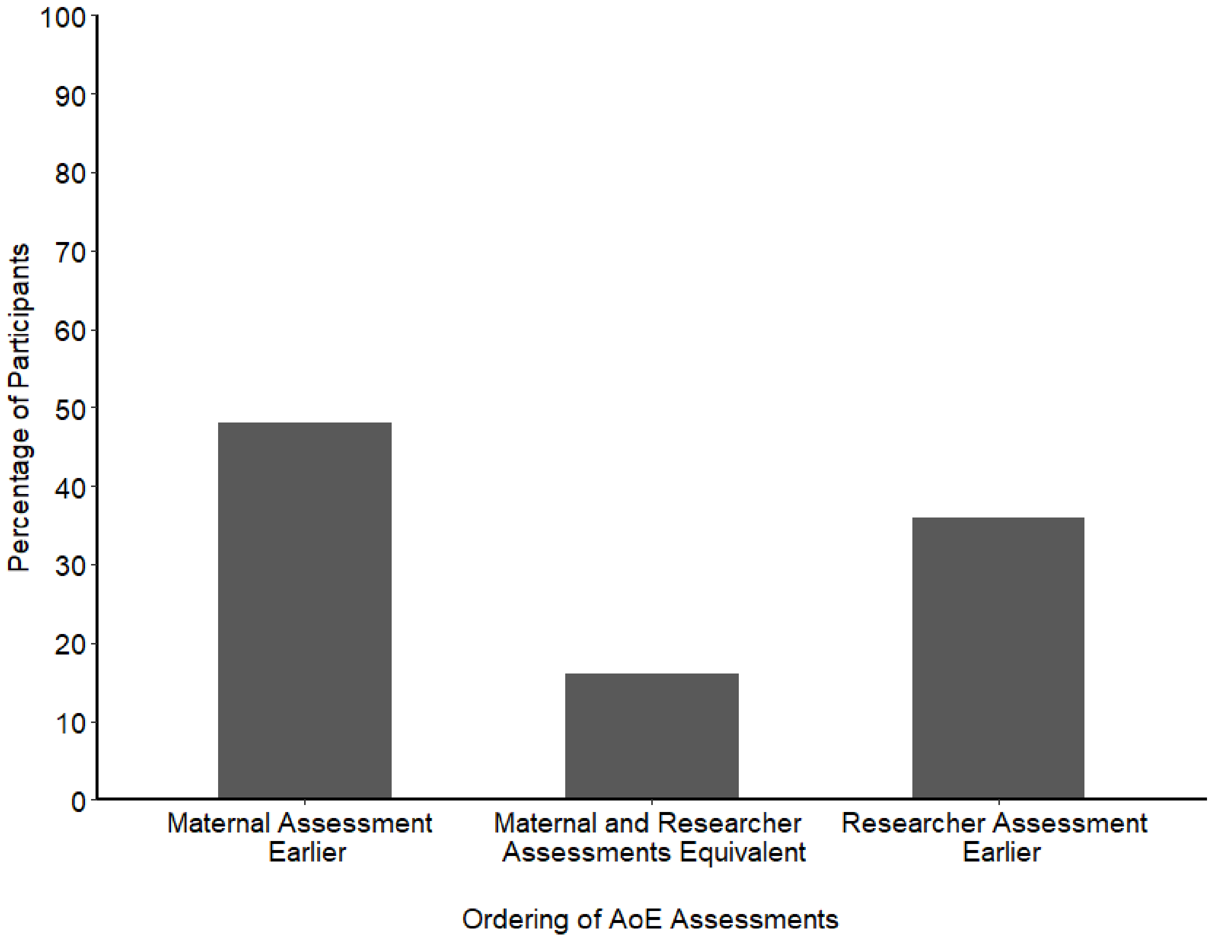
7.2.2.1 Comparison between Maternal Assessments and Researcher Free Play Assessments

Chapter 3 demonstrated that infants produced JA looks earlier in the novel experimental tests than in the free play. Thus, the earlier reports of joint attention looks by researchers may be to do with effectiveness of these tests for eliciting joint attention looks, and the way in which these tests provided excellent conditions for clear assessments of joint attention looks. Thus, a more apt comparison might be between maternal assessments and researcher *free play* assessments. Are mothers' and researchers' assessments more similar when both were observing spontaneous, dynamic engagements with mothers rather than controlled tests?

Figure 7.7 shows the percentages of cases in which maternal and researcher assessments were different or equivalent, with maternal assessments compared with researcher free play assessments.

Figure 7.7

Orderings of Researcher Free Play Assessments of Joint Attention Looks and Maternal Assessments of Joint Attention Looks

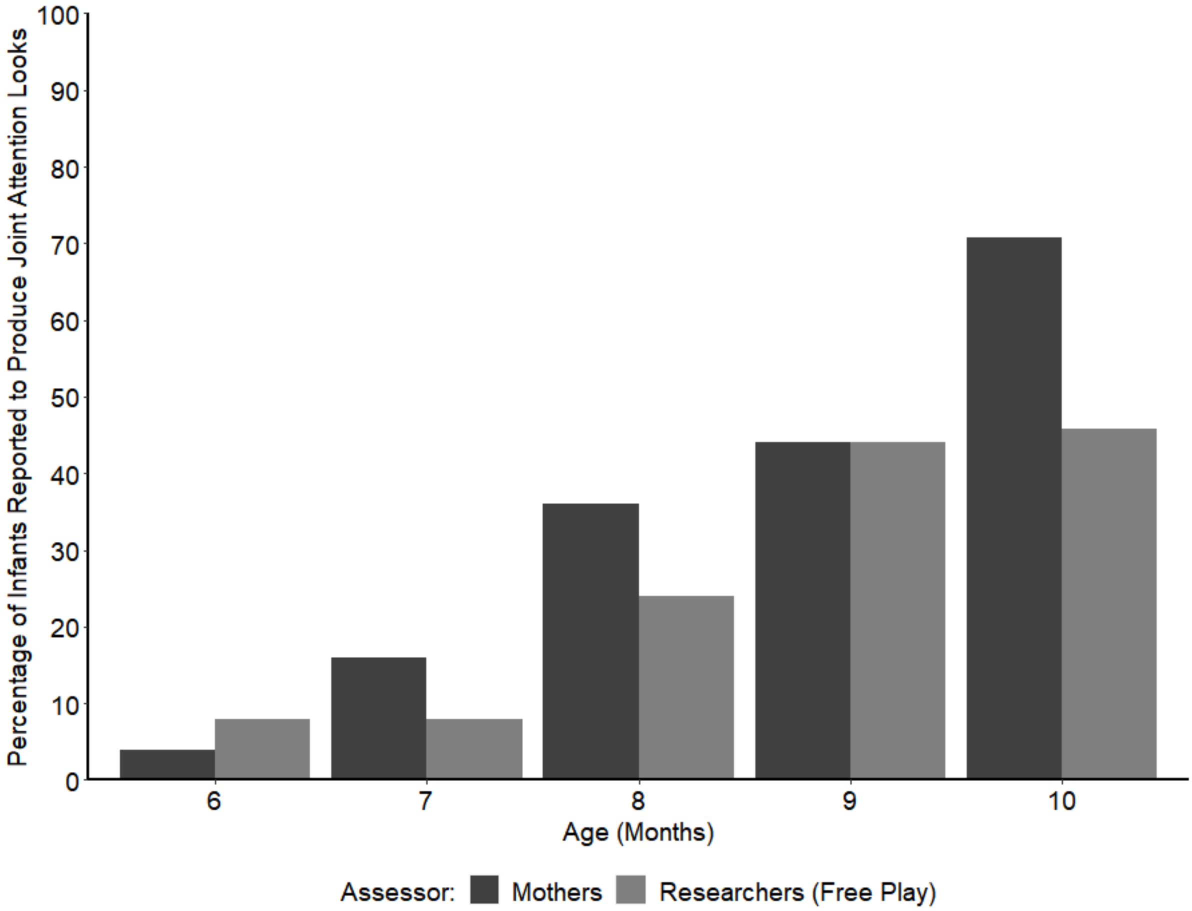


Excluding cases where censoring made the ordering uncertain, it was found that in 12 out of 25 (48%) cases the maternal AoEs were earlier, in 4 out of 25 (16%) cases the AoEs were equal and in 9 out of 25 (36%) cases the researcher AoEs were earlier. The proportion of cases in which mothers identified joint attention looks earlier did not differ from chance levels (two-tailed, $p = 1.0$, 95% CI [0.28, 0.69]), and the proportion of cases in which researchers identified joint attention looks earlier did not differ from chance levels (two-tailed, $p = 1.0$, 95% CI [0.28, 0.69]). Overall, these results indicate that neither mothers nor researchers (from the free play) consistently reported the AoE of joint attention looks at an earlier age.

The next set of analyses focused specifically on confident assessments of joint attention looks (i.e. scores of “2”). Figure 7.8 displays shows the percentage of infants who were assessed to be capable of joint attention looks (scores of “2”) by mothers and by researchers from free play observations.

Figure 7.8

Percentage of Participants who Received a Joint Attention Look Score of “2” at each Month, Comparing Maternal and Researcher Free Play Assessments



To compare relative assessments of pass rates, a GLMM was specified. A Tukey’s HSD post hoc test on assessment type revealed no significant difference between maternal and researcher assessments at any month. This result indicates that maternal assessments and researcher free play assessments were similar throughout the period of assessment.

The final analysis investigated the overall consistency between mothers' and researchers' assessments of scores of "0", "1" and "2" for independent sitting. This was examined by calculating the percentage agreement and Cohen's Kappa coefficient with squared weighting. Percentage agreement was 41.1% and Cohen's Kappa coefficient was 0.19κ, suggesting low agreement.

7.2.2.2 Discussion

Comparing maternal and researcher assessments overall, it was clear that assessments were different, with the researchers identifying significantly more infants producing joint attention looks at months 6 to 9. However, by 10 months, there was no significant difference between mothers' and researchers' assessments of joint attention look production. Additionally, researchers reported the AoE of joint attention looks earlier than mothers in a significant proportion of cases, and overall reliability was low (0.12κ). It is possible that these looks were generally difficult for mothers to assess in earlier months, and became clearer as the infants became able to produce the behaviour more consistently (see Chapter 3). This may be true for researchers and mothers' alike; it was our experience that not all joint attention looks were equally clear to assess, and that it was typically easier to assess the joint attention looks of older infants. It may also be that these differences are akin to the differences found in Chapter 3; that the experimental procedures are more effective at eliciting joint attention looks than free play engagements, leading to high numbers of infants identified as being capable of this behaviour.

Indeed, it is notable that these differences are not present when examining researcher assessments from the free play versus maternal assessments, and that there were no overall differences in relative assessments of joint attention look AoE. These findings provide some evidence that mothers and researchers provide more similar assessments of joint attention looks when drawing from more comparable observational contexts. However, the results of the GLMM are tempered by the measurements of agreement, which found overall low patterns of agreement with scores of "1" included (0.19*κ*). It is possible that a number of these disagreements stemmed from differences in "1" scores.

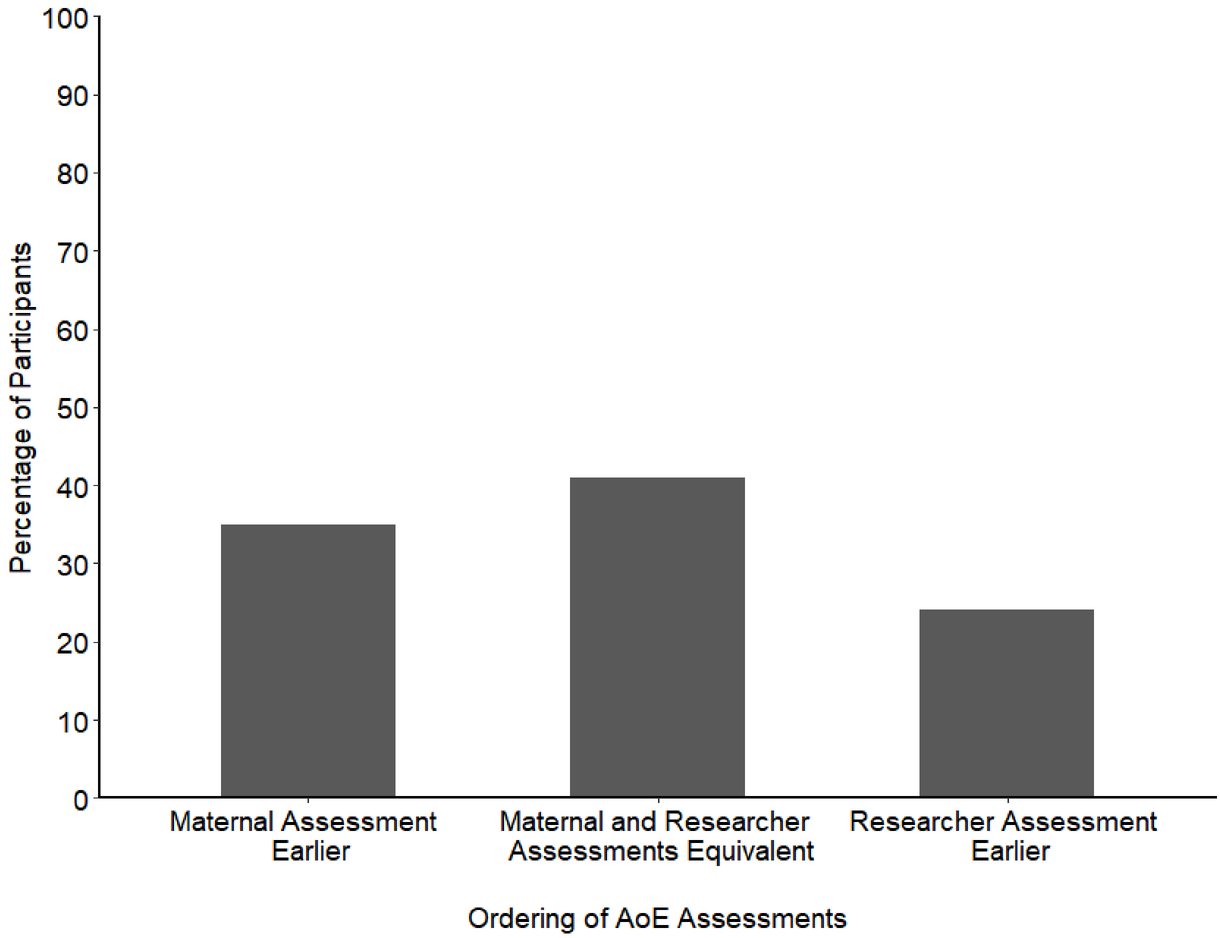
Previous studies have suggested that caregivers are not familiar with terms like "joint attention" or "joint attention looks" (Salter et al., 2021), and do not assess behaviours like joint attention looks consistently with other (e.g. "sharing looks"; Graham et al., 2021). The results of this study provide some evidence that caregivers can indeed identify these behaviours, and even are similar to researchers if considering assessments from free play. The findings of this study may be down to the method applied; the use of interviews allowed mothers to provide detailed descriptions of their infants' relevant capabilities from a range of relevant questions, despite them not using the explicit terminology of "joint attention". However, if joint attention looks are to be accurately assessed in questionnaires, it is imperative to provide sufficiently detailed information for caregivers such that they can know precisely what it is to look for and thus identify these behaviours. The study of Graham and colleagues (2021) found that Hobson and Hobson's (2007) definition of "sharing looks" was insufficient, but it may be that providing more detailed definitions for caregivers can facilitate their identification of this early communicative behaviour.

7.2.3 Showing Gestures

Figure 7.9 shows the percentages of cases in which maternal and researcher assessments were different or equivalent.

Figure 7.9

Orderings of Experimental Assessments of Showing Gestures and Maternal Assessments of Showing Gestures



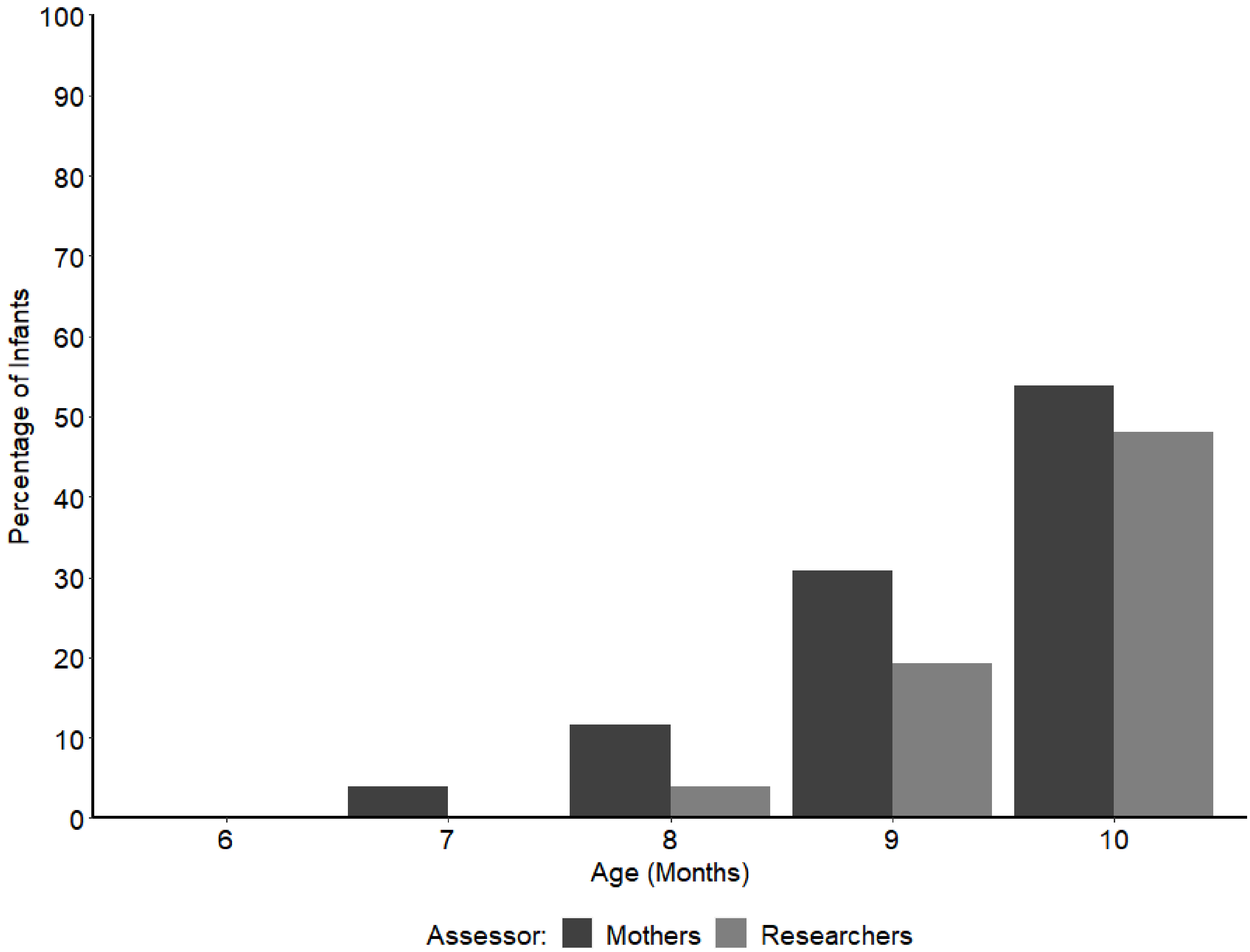
Excluding cases where censoring made the ordering uncertain, it was found that in 5 out of 16 (31%) cases the maternal AoEs were earlier, in 7 out of 16 (44%) cases the AoEs were equal and in 4 out of 16 (25%) cases the researcher AoEs were earlier. The proportion of cases in which mothers reported showing gesture emergence earlier than researchers was not significantly different from chance (two-tailed binomial test, $p = 0.21$, 95% CI [0.11, 0.59]). The proportion of cases in which researchers reported self-locomotion earlier than mothers was not significantly different from chance (two-tailed binomial test, $p = 0.08$, 95%

CI [0.07, 0.52]). Overall, these results indicate that neither mothers nor researchers consistently reported the AoE of showing gestures at an earlier age.

Figure 7.10 displays shows the percentage of infants who were assessed to have produced a showing gesture (scores of "2") by mothers and by researchers.

Figure 7.10

Percentage of Participants who Received a Showing Gesture Score of "2" at each Month, Comparing Maternal and Researcher Assessments



To compare relative assessments of pass rates, a GLMM was specified. Because there were no reports at 6 months, and because there was only one participant who received a score at 7 months, the fitted model only examined scores at 8, 9 and 10 months to avoid an imbalanced model. A Tukey's HSD post hoc test based on assessment type conditioned by age found researchers that assessments did not differ significantly at any month.

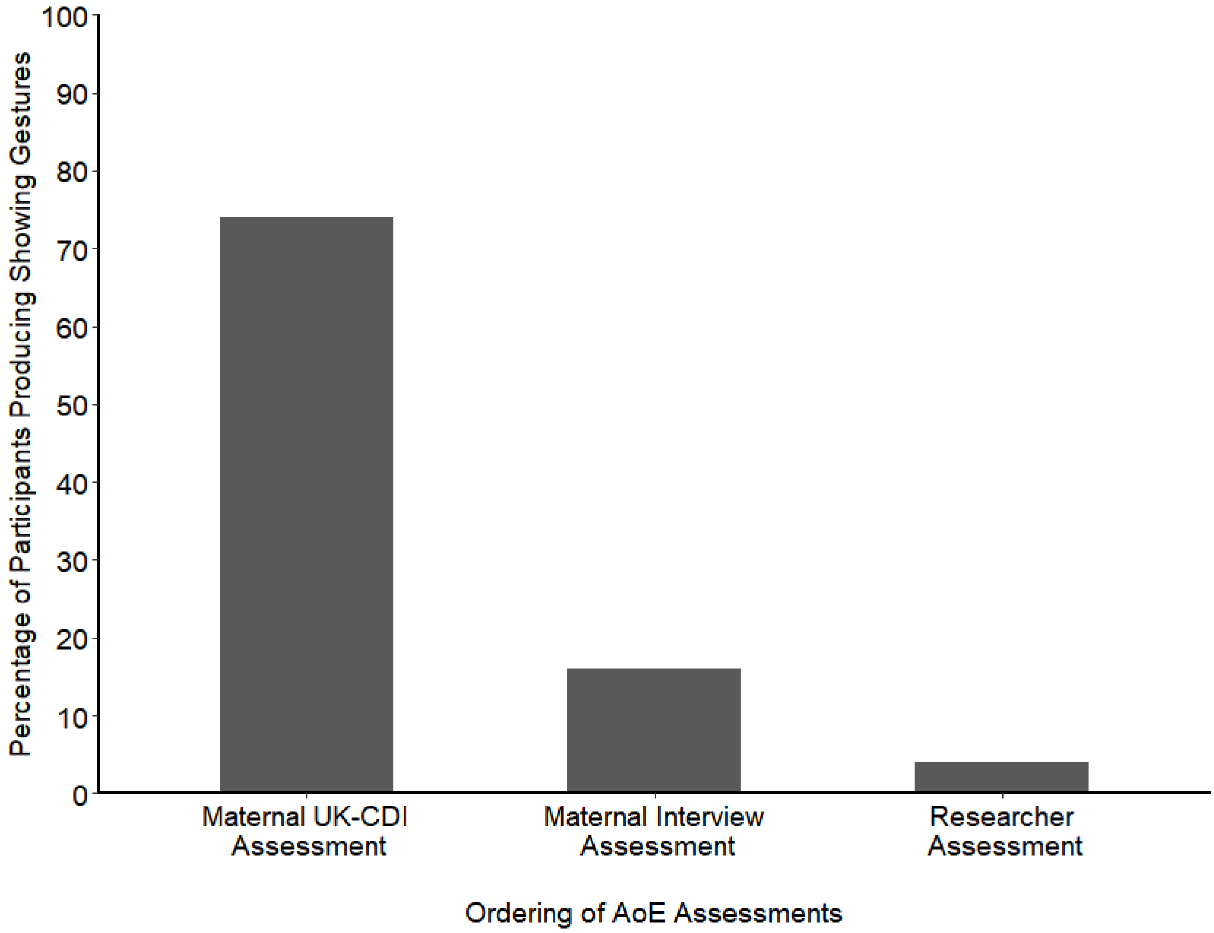
The final analysis investigated the overall consistency between mothers' and researchers' scores of "0", "1" and "2" for showing gestures. Percentage agreement was 69.0% and Cohen's Kappa coefficient was 0.53, suggesting moderate agreement.

7.2.3.1 Comparison between Maternal UK-CDI Assessments and Researcher Assessments

The final set of analyses focused on the reporting of showing gestures when asked a single simple question. The only age at which both UK-CDI and researcher assessments were collected was at months, so the comparison focuses on this age. Figure 7.11 displays the percentage of infants who produced showing gestures at 8 months as recorded by the interviews, the researcher assessments and the mothers' responses to the UK-CDI.

Figure 7.11

Percentages of Participants who Produced Showing Gestures at 8 Months as Reported by Different Assessments



At 8 months, 1 out of 25 (4%) infants was reported to produce showing gestures according to the researcher assessment, 4 out of 25 (16%) by maternal interview assessment and 17 out of 23 (74%) by maternal UK-CDI assessment. McNemar's tests showed a significant difference in the proportion of reports of showing gestures between maternal UK-CDI and maternal interview assessments ($n = 24$, $p < 0.001$), and between UK-CDI and researcher assessments ($n = 24$, $p < 0.001$). Showing gestures at 8 months were significantly more likely to be reported by mothers when completing the UK-CDI than when assessed by interview, and as compared with researchers' assessments.

7.2.3.2 Discussion

There are several key findings to take away from these results. First, there were no significant differences between assessments of showing gesture production, nor assessments of showing gesture AoE, between mothers and researchers. The overall assessments, using scores of “0”, “1” and “2”, found that maternal beliefs and researcher assessments were generally similar, with a moderate agreement (0.53κ). Overall, these results indicate that mothers generally report the development and emergence of showing gestures in a manner similar to researchers, in line with previous claims about caregiver reports of intentional communicative gestures (Eadie et al., 2010).

Additionally, the results demonstrated the effect of asking a single question regarding showing gestures (“Extends an arm to show you something she or he is holding”): it led to a significantly higher proportion of positive responses regarding showing gesture production for that month. Whilst this result is only from one time point (8 months), it suggests that a less specified question may lead more positive responses in comparison to researcher assessments, as well as more detailed forms of assessment (i.e., interviews) that provide opportunities for elaboration and assess participants’ confidence in their response. Assuming the interviews provided a more fine-grained and accurate form of assessment from the mothers than their UK-CDI responses,

We also found that some mothers responded positively to the question, “Does your infant show you interesting objects? If so, how do they do this?”, but went on to describe behaviours that were not showing *gestures*, but rather behaviours that appeared to be joint attention looks. Thus, questionnaires that aim to assess gestures like showing may need to break the gesture down into multiple components, in order to provide a composite score that ensures various criteria have been met, both in terms of communicative intent and in terms of behavioural form. These responses also provide further support for the notion that at least some caregivers notice and report joint attention looks, even if they lack an explicit vocabulary for describing these looks.

It is also important to again stress that we have avoided taking researcher assessments as objective and maternal assessments as not. Indeed, there were cases in which mothers provided detailed descriptions of showing behaviours, despite no such behaviours being produced by infants during the lab visits, suggesting that the infant had simply not produced the ability despite it being in their behavioural repertoire. Researchers may be hesitant to accept caregiver reports that are in conflict with lab-based assessments, but if clear, reliable tools can be developed for obtaining caregiver assessments of communicative abilities, they can supplement or be combined with measures coded from recorded free play interactions or elicitation paradigms.

7.3 General Discussion

This study has provided new data on maternal assessments of early communicative behaviours, and is the first to longitudinally compare maternal and researcher assessments of the same infants, providing new insights into the relative reporting of the emergence and development of early motor and communicative behaviours. For independent sitting and self-locomotion, assessments were broadly similar, though with some differences when these behaviours were just starting to emerge. These findings suggest that care must be taken with assessments of even relatively clear and salient behaviours like motor skills, and that the very beginnings of the emergence of these abilities is a time where differences can emerge between caregiver and researcher assessments.

For joint attention looks, caregiver judgments were typically earlier than researcher judgements, when comparing assessments from all tasks. It was suggested that these issues stem at least in part from a lack of a clear, commonly used set of behavioural criteria for assessment (Graham et al., 2021; Salter et al., 2021) as well as the challenges of assessing these behaviours from complex and dynamic engagements versus controlled procedures. However, by the time the infants were 10 months of age, no significant difference was found between assessments. Moreover, when maternal and caregiver assessment were compared using researcher observations from free play, confident assessments of joint attention looks were not significantly different at any month. These results suggest that, despite being a behaviour that is complex to identify and assess (Eadie et al., 2010; Graham et al., 2021), caregivers are capable of identifying and report these behaviours.

For showing gestures, maternal beliefs and researcher assessments were similar. However, as the CDI data on showing gestures revealed, using a brief question with limited qualification and limited response options led to a significantly larger proportion of mothers reporting these gestures as compared to both researcher assessments and mothers' assessments from the interviews. Given the mothers' lack of agreement with themselves, these findings imply that care must be taken to have sufficiently detailed questions about communicative behaviours in order to obtain reliable assessments.

The findings of this study provide insights relevant to the development of diagnostic tools for assessing infants' communicative capabilities. They align with previous work suggesting that behaviours with clearer diagnostic criteria and more salient and easily observable characteristics will be assessed comparably by caregivers and researchers (Eadie et al., 2010; Reznick & Schwartz, 2001). The main challenge for such tools is effectively establishing common criteria between caregivers and researchers. For communicative behaviours, clear descriptions of the relevant behavioural forms can be provided, and the relevant behaviours could be broken down into their behavioural components, providing separate measures for facets like behavioural form and communicative intent. For example, there may be cases in which the caregiver reports that the infant produces relevant behavioural forms (e.g. holding out an object) but without the appropriate communicative intent (e.g. to show the object), or in which the caregiver is convinced the infant has a communicative intention, but is not able to produce the relevant behavioural form (see Chapter 4). By breaking down different components, a clearer picture of infants' actual capabilities may emerge.

In addition, depending on how accurate the report aims to be, and how many items are on the questionnaire, researchers might consider adding in further checks to establish whether the behaviours were produced with consistency and in a clearly intentional manner. In a similar vein, it may be beneficial to have measures of confidence on the part of the caregiver, rather than using scales that focus primarily on regularity (i.e. "never", "sometimes" and "often"). This approach would provide a more conservative measure of caregiver assessments, ensuring at the very least that caregivers had strong reasons for believing that their infant was capable of a certain behaviour, even if these reasons were not those that researchers would apply.

Finally, it is important to note that there are different methods that can provide insights into caregiver views on communicative development. This study has justified the use of interview methods, but there are a variety of tools at researchers' disposal. One way to obtain a clearer understanding of how caregivers understand communicative development is to examine relations between different kinds of methods that can provide insights into caregiver understanding of interaction and communication. Previous research has examined caregivers' spontaneous utterances and interactive responses in the context of live interactions, and used these data to draw conclusions about caregivers' understanding of their infants' social behaviour (e.g. Meins, 1997; Shai & Meins, 2018). Caregivers' implicit beliefs about their infants' intentions and communicative capacity have been inferred from interview responses (e.g. Degotardi et al., 2008), and researchers have assessed explicitly held views about communication through interviews or questionnaires (e.g. Eadie et al., 2010; Fenson et al., 1994) or by asking for different participants to judge the same video examples (e.g. Adamson et al., 1987; Graham et al., 2021; Zeedyk, 1997).

These different situations provide different kinds of data. There are implicit and explicit measures, and live versus reflective responses. There are checklists examining a wide range of behaviours and interviews focusing on a specific subset of behaviours. While many of these studies involve caregivers answering questions about their own infant, there are some studies that involve participants assessing the behaviour of others' infants. However, quite how all these various measures relate to one another is not well understood, and a thus is important for future work to view caregiver understanding as a complex, multifaceted construct (Degotardi et al., 2008).

7.4 Conclusion

This chapter has argued that caregiver assessments provide an important and unique form of insight into social and communicative development (Reddy & Trevarthen, 2004), and have the potential to provide data with large samples and regular sampling frequency from families' daily lives (Adolph et al., 2008; Eadie et al., 2010; Nordahl-Hansen et al., 2014; Sachse & Von Suchodoletz, 2008). This study is the first to longitudinally compare maternal and researcher assessments of the same infants, in order to provide insights into the relative reporting of the emergence and development of early motor and communicative abilities.

CHAPTER 8

CONCLUSION

The thesis has sought to investigate the very beginnings of joint attention and communication in infancy, providing new insights into the twin issues of joint attention's definition and development. This conclusion will draw together the findings of the thesis, before looking forward to how these findings might guide future empirical and theoretical research. First, the main empirical findings of the thesis will be drawn together and discussed, and future directions for research will be charted. Then, several big-picture conceptual issues that have been raised by the thesis will be discussed, and possible future directions for addressing these issues will be outlined.

8.1 The Origins, Antecedents and Interpretations of Social Development in Early Infancy

The thesis has made a number of novel empirical contributions, providing new methods and data that contribute to the study of joint attention and communication and our understanding of their development in infants' first year. There are three main sets of findings to highlight.

8.1.1 Understanding the Very Beginnings of the Emergence of Joint Attention and Communication

The introduction highlighted that there are still debates over when joint attention emerges in development, and that a key definitional issue is understanding what makes joint attention joint. The findings of this study indicated that joint attention and communication abilities emerge gradually between 6 and 10 months, potentially starting to emerge even sooner, rather than suddenly at around 9 months (Stern, 1985; Tomasello, 1999; Trevarthen & Hubley, 1978). These findings are consistent with previous work that stresses the importance of understanding the months leading up to 9 months, providing evidence that key developments in joint attention and communication abilities are occurring at these ages (de Barbaro et al., 2013; 2016; Hoehl & Striano, 2013; Rossmanith et al., 2014; Striano & Bertin, 2005a; Striano et al., 2009). However, this study goes a step further than these studies by providing a novel experimental paradigm with a stricter definition of communicative joint attention, along with detailed behavioural coding of joint attention looks.

However, there are still further complexities to be explored regarding the emergence of joint attention and communication abilities in infants' first year. One issue observed in Chapters 3, 4 and 5 is the consistency of emergence of different abilities, with abilities appearing at an earlier session but then not at the following session or sessions. As has been suggested throughout the thesis, this pattern may simply be variance due to factors such as infant mood or energy, or variations in the stimuli used. However, given the increasing consistency observed in the case of joint attention looks, an alternative view is that these abilities become increasingly consolidated over time. Assessing these abilities with an increased sampling frequency and with a larger sample of infants would allow an even more fine-grained analysis of developmental trends.

In Chapter 6, few relations were found between different abilities. The relation between joint attention looks and showing gestures was in line with previous work suggesting relations between abilities used to initiate joint attention (Carpenter et al., 1998; Salo et al., 2018). However, these results would be clearer if a larger sample and a wider age range were used to reduce censoring issues. A further approach for assessing interrelations amongst joint attention, communication and other abilities could be to not only focus on the earliest emergence of these abilities, but also on the point at which they are consolidated. It may be that it is the point at which joint attention has emerged in a consistent manner, being well-established in infants' behavioural repertoires, that relations to other social abilities can be identified. This may be the case because it is once these abilities are well-consolidated that they can begin to reliably be detected (see Chapter 7) and thus elicit responses from caregivers, paving the way for new kinds of social interactions that facilitate the emergence of later social abilities. Alternatively, it may be the case that it is only when infants are able to flexibly employ abilities like joint attention looks that they can begin to integrate them into engagements involving communicative gestures and, later, language.

A further avenue for future research is to build on recent work by Choi and colleagues (2021), who found that relations between joint attention abilities and later sociocognitive abilities can differ depending on the months at which they are assessed. For example, they found that showing and giving gestures at 10 months were a better predictor of later language abilities at 18 months compared to pointing at 10 months. However, from 14 months, pointing was the stronger predictor of language abilities at 18 months. They noted that, with age, showing and giving were supplemented by pointing gestures, rather than being replaced by them; infants still continued to produce similar quantities of shows and gives at 10 and 14 months. Thus, assessing whether rates of joint attention look production are related to later joint attention abilities may similarly vary depending on the ages at which infants are engaging in these abilities; relations may fall away as infants age and grow their repertoire of joint attention abilities.

8.1.2 Developmental Antecedents of Joint Attention and Communication

The thesis has made the case that it is not only important to focus on the emergence of mature or conventional forms of early social and communicative behaviours, but to identify and chart the developmental processes that precede the emergence of these forms. Any mature or conventional behaviour will be preceded by a developmental process, and these processes need to be better understood. Only then can we understand the very beginnings of joint attention and communication.

In Chapter 3, it was difficult to draw any strong conclusions about the developmental antecedents of joint attention looks, given that some of the infants were already producing joint attention looks at 6 months. However, those infants who had not yet produced joint attention looks at 6 months were spontaneously looking to an adult in response to a stimulus (i.e., received a score of "1"). Whilst this does not constitute communicative joint attention, it does potentially indicate a capacity to engage in patterns of behaviour that are both spontaneous and triadic (rather than solely passive and triadic, scaffolded by caregiver support; see Bakeman & Adamson, 1984; Rossmanith et al., 2014). This behaviour may indicate that the pathway to infants being capable of joint attention looks is more complex than simply moving from passive to active; rather, along with being guided by caregivers (as in Bakeman and Adamson's, 1984, "supported joint engagement"), they also actively contribute to the flow of the interaction by spontaneously looking to their caregivers, taking an active role, even if not yet establishing truly joint attention. There is thus a need for further research that can explore the very beginnings of infants' capacity to initiate joint attention. Firstly, there is a lack of experimental work that has sought to examine infants' capacity to initiate joint attention. Despite numerous paradigms focusing on attention following, there is a relative lack of studies focusing on the initiation of joint attention. Second is the issue of the prior developments that enabled some of the infants to be capable of joint attention looks by 6 months of age. Future work drawing on the paradigm developed in Chapter 3 could focus on younger infants and examine prior developments such as earlier dyadic social behaviours (Striano & Rochat, 1999) or earlier non-communicative attention coordination (Bakeman & Adamson, 1984; Striano & Bertin, 2005a; Striano et al., 2007).

The issue was also explored in Chapter 4, where incipient forms of conventional communicative gestures were examined. The findings of Chapter 4 represent a first step towards cataloguing and describing the kinds of behaviours that might precede some of infants' earliest communicative gestures. However, there was significant diversity in the incipient gestures that were observed, and thus it is necessary to build on these findings, particularly with early showing, giving and requesting gestures, in order to provide further clarity on the developmental processes involved in the emergence of conventional communicative gestures. Future work, following the blueprint of the pointing literature, can seek to identify further potential incipient gestural behaviours and can examine the possible developments and processes that enable these behaviours to become conventional communicative gestures (Boundy et al., 2019; Kettner & Carpendale, 2018; Matthews et al., 2012).

Whilst there are more questions to explore, the thesis has repeatedly made the case for not viewing the production of mature or conventional behavioural forms as the starting point of their development, but rather an important phase that is both preceded by a developmental process, and is later elaborated into more complex behavioural forms. The blueprint for this view is already available in the rich and detailed literatures on attention following (Bertenthal et al., 2014; Flom et al., 2007; Moore, 2008; Shepherd, 2010) and pointing (Carpendale & Carpendale, 2010; Kettner & Carpendale, 2018; Liszkowski & Rüther, 2021; O'Madagain et al., 2019), which both look backwards to the origins of these abilities, and look forward to the developmental consequences of being capable of these abilities, including the other social and cognitive abilities whose emergence and development they predict.

8.1.3 The Role of Caregivers in Understanding the Origins of Joint Attention and Communication

The final contribution of the thesis was to highlight the nuances and complexities involved in caregivers' judgements of early communicative development. As discussed in Chapter 7, there are a number of benefits for researchers in being able to draw upon caregivers' insights into the development of joint attention and communication. For example, developing clear and consistent means of obtaining caregiver assessments of early communication has practical and theoretical benefits. It enables larger samples and higher sampling frequency, with the impact of infant mood and energy reduced and the speed of data collection increased (Eadie et al., 2010; Nordahl-Hansen et al., 2014; Sachse & Von Suchodoletz, 2008). It also means data are coming from those who have the most consistent and regular exposure to the infant, observing them and interacting with them more often than any researcher could (Adolph et al., 2008).

Chapter 7 focused on the relative reporting of early motor and communicative abilities by mothers and researchers, presenting evidence that mothers' reporting of these early abilities was not straightforwardly a matter of identifying these abilities as emerging earlier than researchers would assess them as emerging, as one might predict. While for motor abilities (independent sitting and self-locomotion), there were some differences in reporting at the point at which the abilities were starting to emerge, showing gestures were reported in a broadly similar manner, and joint attention looks were reported as emerging earlier by researchers, with different reporting until the infants were 10 months old.

These data suggest that caregiver reports can potentially serve an important tool for identifying infants' early communicative behaviours, but that care must be taken when using caregiver reports to assess the very beginnings of infants' social and motor behaviours. This is not to say that this is because caregivers are not accurate; it was plausible that caregivers in fact had a clearer sense of the emergence of social and motor abilities than researchers. Rather, at these early stages, there may be a greater chance of researchers and caregivers assessing these abilities in different ways or with different criteria. It was found that even for joint attention looks, which are not widely discussed in common discourse (Salter et al., 2021) and thus may not have clear common criteria of assessment (Graham et al., 2021), researcher and caregiver assessments were eventually similar when the infants were 10 months, and were similar when caregiver assessments were compared with researchers' free play assessments. The challenge for developing assessment tools is to create the right set of questions that can ensure that caregivers and researchers are looking out for the same behaviours. This challenge is part of the broader challenge of developing clear means of assessing key early joint attention and communication abilities (Boundy et al., 2016; Gabouer & Bortfeld, 2021; Graham et al., 2021; Stephenson et al., 2021).

A final point to highlight regarding the role of caregivers is the way in which the "second-person perspective" (Gallagher, 2001; Gómez, 1996; Moore & Barresi, 2017; Reddy, 1996, 2010; Schilbach et al., 2013; Siposova & Carpenter, 2019) informs our understanding of caregivers' insights into the development of joint attention and communication. Adopting this approach means recognising the distinct epistemic insights into communication that are gained by being an active participant in (rather than passive observer of) social interactions. Chapter 7 embraced this approach by avoiding taking the researcher assessments as objective and the caregivers' as not. However, it did not examine in detail the mothers' reported experience of early communicative abilities. This is a potential further use of the collected data. By examining the different ways in which caregivers interpreted their infants' early communicative behaviour, new insights can be gleaned regarding the kinds of behaviours that were used to determine when their infant is communicatively engaging with them, which in turn may provide an insight into how caregivers respond to their infants and shape their engagements.

8.2 Conceptual Issues in the Study of Joint Attention and Communication: New Directions

This chapter will finish with some big-picture reflections on the theoretical themes discussed in this thesis, not only as they pertain to joint attention and communication, but also broader issues of social development.

8.2.1 Communication and the Dyadic to Triadic Transition

A central theoretical question in understanding the origins of joint attention is how infants transition from dyadic engagements to triadic engagements. There are two key issues to address. The first issue is the possibility of identifying intermediary steps between dyadic and triadic engagements (Bakeman & Adamson, 1984; Moll et al., 2021; Reddy, 2005, 2010). The second issue is that researchers examining the development of joint attention needs to take the question of "jointness" seriously (Carpenter & Liebal, 2011; Hobson, 2005). The shift from dyadic to triadic involves more than a "structural" shift from person-person to person-person-object engagement. Rather, there is a need to understand when joint, communicative triadic engagements emerge, as opposed to engagements that might have a triadic structure but are not truly joint.

The thesis builds on these two sets of conceptual considerations, highlighting a number of important issues. First, the thesis has helped examine intermediary stages between dyadic and triadic engagements, discussing when these intermediary forms might be understood as communicative. Evidence from Chapter 3, building on previous work such as that of Striano and colleagues (Striano & Bertin, 2005a, 2005b; Striano et al., 2009), suggested that infants produce spontaneous behaviours with a triadic structure (e.g. looking from a stimulus to a caregiver, but non-communicatively) prior to integrating communicative expressions so as to produce a joint attention look. Chapter 4 proposed that incipient gestures might also be intermediary forms between dyadic and triadic engagements. For example, infants' incipient showing gestures appeared (in some cases) to be communicative acts that were not clearly triadic, such as when the object was raised but seemingly incidental to the infant's engagement with their mother, and in cases where the target object was not held stable and thus not a clearly individuated referent.

An important distinction amongst these potential transitional forms can be identified from these examples. One kind of case involves acts that are clearly triadic, but non-communicative, such as infants' spontaneous looks to an adult in response to a stimulus. The other kind of case involves acts that are communicative, but not clearly triadic, such as the communicative but not clearly individuated show. It is plausible that the eventual capacity for these kind of behaviours are constructed out of these different kinds of prior abilities, as infants learn both how to coordinate attention with others to a target of interest, and how to communicate about referents in the world.

A further contribution of the thesis is to highlight the need for greater diversity in the modalities used to investigate joint attention, both those of the targets of joint attention and also the kinds of behaviours used to achieve joint attention (Battich et al., 2020). Greater diversity in modalities promote new, more nuanced ways of understanding notions of dyadic and triadic engagement. For example, non-visual stimuli raised a number of issues for views of joint attention that emphasise coordination of visual attention to a location in space. In Chapter 3, hidden auditory stimuli were used, meaning that there was no clear anchoring point in space from which the infant could alternate gaze. Further examples were discussed, such as non-localised auditory stimuli (e.g., the sound of falling rain), but there are many more that could be examined and have not yet been, such as infants' sharing of tactile sensations, tastes and smells.

Non-visual stimuli cannot straightforwardly be embedded in the classic "triangle" of joint attention in a manner that is as relatively simple as when there is a clear, discriminable object to which co-attenders can attend. Indeed, the focus on objects may be a consequence of two theoretical tendencies; first, the tendency to focus primarily on gaze in studies of joint attention, and second, the tendency to view attention as a "spotlight" in discussions of joint attention (Botero, 2016; Hobson & Hobson, 2011; Moll et al., 2021; Siposova & Carpenter, 2019). If these two views are adopted, it is not clear how to accommodate non-visual cases, nor mixed-modality cases. Conceptual accounts of joint attention thus need to incorporate varied modalities into their theorising from the outset, both in terms of the stimuli examined and in terms of the multimodal behaviours infants use to coordinate joint attention (Battich et al., 2020; Botero, 2016; Esteve-Gibert & Prieto, 2014; Little et al., 2016). This issue is also pertinent to cross-cultural investigations of joint attention, as it has been identified that non-Western cultures employ different modalities in different frequencies during interactive engagements, with less of a focus on gaze (Keller, 2013; Little et al., 2016). By taking different stimuli seriously, it is possible to go beyond a simplistic "triangular" view of triadic joint attention, towards one that can account for the varied stimuli infants can share, as well as the different ways that sharing might look in such cases.

In summary, this thesis is aligned with others who call for more attention to be paid the development period in which dyadic engagements are transitioning into triadic engagements (e.g. de Barbaro et al., 2013; Hoehl & Striano, 2013; Moll et al., 2021; Rossmanith et al., 2014). This requires a deeper understanding of potential transitional forms between dyadic and triadic engagements, as well as understanding infants' sharing of different stimulus types. A particular focus of this thesis has been to stress the importance of focusing on the development of joint attention not solely in terms of a structural shift from dyadic to triadic, but also to focus on how communicative dyadic engagements become "truly joint" communicative triadic engagements.

8.2.2 Understanding Communicativeness in Joint Attention: From Behavioural Parts to Meaningful Wholes

Researchers have highlighted that humans appear to know intuitively and instantaneously when someone is attempting to communicate with them (Carpenter & Liebal, 2011; Csibra, 2010). Yet limited work has sought to operationalise the quality of communicative looks, both in terms of differentiating "joint" or "sharing" behaviours from other kinds, and in terms of assessing what might be the "message" of such looks. The thesis has explored the key conceptual issue of how to assess communicativeness in a manner that is clear and consistent across different studies.

Chapter 3 provided an approach to infants' initiation of joint attention that emphasised its joint, communicative nature, rather than focusing solely on the coordination or alternation of gaze. It was argued that there are identifiable behavioural features that are coordinated to produce a communicative joint attention look, such as the coordination of facial expressions and vocalisations with looking behaviour. The approach taken aligns with the recent work of Graham and colleagues (2021), who suggest that coding approaches to behaviours like "sharing looks" (Hobson & Hobson, 2007) require focusing on a range of coordinated behavioural features, rather than taking a holistic approach that focuses on an overall impression of the jointness of an infant's behaviour. Though, as Graham and colleagues note, it is to Hobson and Hobson's credit that they at least attempted to identify the quality of joint attention looks; even attempting to do so is rare in previous studies.

It is important for objective criteria and behavioural features to be identified that can enable researchers and caregivers alike to identify what makes a look communicative. However, this is the most limited aspect of current assessments of joint attention. Besides the work of Hobson and Hobson (2007), work on coordinated smiles (Jones & Hong, 2001; Striano & Bertin, 2005a; Striano et al., 2009) and the coding strategy outlined in this thesis (Chapter 3), there is very little work that has sought to address the key issues of what specific behavioural features create the sense of jointness. There may be a number of subtle changes in facial behaviours, from pupil dilation, facial musculature (eyes, eyebrows, mouth) that combine to create looks that are experienced as communicative. Graham and colleagues highlighted behaviours such as look duration, mutual gaze duration and communication by both interaction partners. But while these behaviours are informative, it is not clear that they get at the essential issue of what makes a look be experienced as joint (particularly given that the notion of communicativeness itself needs operationalising). Additionally, Graham and colleagues note that there are interactive cues that are accessible to the individual who is participating in the interaction which are not necessarily clear when observed from a third-person perspective.

Consider, for example, how mothers tried to articulate how they experienced their infants' efforts at communication, particularly through joint attention looks:

> Participant 13, 9 months: "I think she still looks at me the same amount but I think the way that she's looked at me has really slightly changed… Like it's as if she's a little bit more aware."

> Participant 15, 6.5 months: "There's something about the look in his eye - it's like he's trying to tell you something, not just glancing. He's trying to tell you something.

There's something about the way his eyes change when he's trying to get something across to you. There's a different intensity to it."

Participant 22, 10 months: "I would say there's different looks now, she's kind of almost got that cheeky 'I'm doing something I shouldn't be doing!' look, then she's got the 'Oh look at me I'm being cute and I'm smiling, and this is nice!' look. So I would say sometimes it's kind of like the look in her eye has maybe changed, it's not just a, I don't know how to describe it."

Participant 24, 9 months: "If she does something or if she notices something new, like the telly [television] coming on, she might kind of look at you like 'Did you see that as well?'" [E: Is there something about the expression she has? Like is it on her eyes or face?] "I don't know. [To baby] It's just your face isn't it? Just get that feeling, don't we?"

These quotes suggest that there are behavioural cues that indicate a sense of communicativeness, but that it is challenging to articulate what exactly these are. Indeed, as experienced from within the interaction, it is apparent that these behaviours are not experienced as bundles of different behaviours, but as an experiential gestalt in which the different behaviours combine into a meaningful whole (Reddy & Trevarthen, 2004). This is suggested by phrases referring to "the way she looks at me" and "something about the look in his eye." It is also clear that there are different kinds of joint look that can be experienced. Terms such as "cheeky," "knowing" and "conspiratorial" suggest that there is variety amongst different kinds of communicative looks, even at these young ages.

The issue here is this: it seems both theoretically necessary and empirically possible to articulate reliable, objective behaviours that infants produce, and to examine how these behaviours are coordinated, in order to provide consistent assessment of the joint or communicative nature of infants' behaviours. However, the problem is putting all these different categorised behaviours back together again to really make sense of the experiential gestalt of communication. There is a problem of "not being able to see the forest for the trees"; however many trees are identified, the challenge of being able to get a sense of the forest remains. It is thus necessary not only to identify more and more different behavioural components, but also examine experiences of what communicative looks mean, both to those experiencing the interaction and those observing interactions "from the outside." This means there is a role to play for interview, diary and video assessment (as in Adamson et al., 1987 and Graham et al., 2021) methods, which focus on analysing how individuals make sense of behaviours as meaningful acts (rather than as clusters of behavioural components). This perspective aligns with that of Bruner (1990), who emphasised the role of meaning in understanding the mind, urging that "psychology stop trying to be 'meaning-free' in its system of explanation" (p. 20). A consequence of this view is the importance of understanding different systems of meaning- for example, across diverse cultures and socioeconomic conditions- that may have different ways of understanding and experiencing communication.

In summary, whilst the necessity of identifying objective behavioural features that contribute to identification of communicative behaviours has been affirmed in this thesis, it is also vital that this does not neglect the importance of the meaningfulness of these behaviours as they are experienced when combined together in the context of an interactive engagement. This means that there is a genuine role to be played by methods that explore the experience of communication, such as through diary, interview and video assessment methods. However, these methods will likely be most effective when combined with efforts to identify consistent and reliable behavioural features that underpin the meaningful experiences of communication.

8.2.3 'Tadpoles with Legs': Incipient and Fragile Behaviours

The next conceptual issue that the thesis has highlighted is the need to understand the developmental processes that precede the emergence of key early joint attention abilities. A number of researchers have come up against this issue, using a variety of terms to try to capture these early antecedent or precursor behaviours. Meltzoff and Brooks (2007) used the image of a "tadpole with legs" (p. 218) to describe the "connecting steps" (p. 218) between earlier and later forms of gaze following. Butterworth (2003) described infants' early pointing behaviour as "embryonic" (p. 12), while Kettner and Carpendale (2018) used the term "incipient" (p. 250), as well as categorising a variety of different early precursors of pointing behaviour (e.g. "slip-out points" and "touch-to-refer"). These terms are all trying to get at a sense in which behaviours are part of a developmental pathway along which various behavioural forms lie, from the behavioural equivalent of frogspawn all the way to the behavioural equivalent of a frog.

Of course, this is not to say that development is complete once the behaviour is first identified in its mature form. A further form of conceptual vocabulary is also needed for capturing the emergent nature of behaviours that have only just become part of the infant's skillset, which subsequently become both more consistently and complexly employed. To get at this notion, Graf and colleagues (2014) described infants' capacity to imitate at 6 months as "fragile competence." The use of fragility is importantly different from incipient or embryonic. It connotes that the behaviour is genuinely within the infants' repertoires, but is not used consistently, rather than that the infant is only capable of behaviours that are on the developmental pathway to the mature or conventional form. In this study, for example, it was suggested that those infants who only produced a single joint attention look at a given session had a fragile competence, later becoming more consistent in their use of the ability when they produced joint attention looks in multiple tasks. It is reasonable to assume that even when this behaviour became a consistent part of those infants' behavioural repertoires, it did not mark an end-point for that behaviour's development. There is still more to learn and develop regarding how joint attention looks might be used in the context of interaction, particularly as they start to be coordinated with communicative gestures and language. This facilitates both variety and explicitness in the infants' communicative efforts, for example in terms of their capacity to convey different affective tones (Adamson & McArthur, 1995; Moll et al., 2021). It was also highlighted that behaviours like showing gestures can undergo further development, for example as infants become able to show different aspects of an object rather than the whole object (e.g., the wheels of a toy car rather than the car as a whole).

Considering both these sets of issues - the development of incipient forms and the transition from fragile to consolidated abilities - requires taking a longer view of development, rather than focusing on a single slice in time. It requires we "look before the onset" (Adolph et al., 2008, p. 450) in order to truly understand how behaviours develop. The value of longitudinal data is thus clearly apparent for addressing these issues, though it is similarly important to chart findings across multiple studies to build a coherent view of what infants are capable of across their development, and how this varies with changes in social, cultural and economic conditions (Henrich et al., 2010; Nielsen et al., 2017). Consideration of these issues also requires a clear articulation of the nature of behavioural transitions across development. In particular, if we are to claim that a behavioural capacity has moved from "absent" to "present" or "present in some fragile form" following some kind of qualitative shift, it is necessary to be able to clearly stipulate the nature of that transformation and the processes that precede it (Kagan, 2008). In the study of joint attention and communication, there is still much more scope to explore the full extent of the developmental trajectories of key abilities, from joint attention looks to communicative gestures.

8.2.4 Rethinking the 9-month Revolution: A Role Shift?

The final conceptual issue to be considered is that of the “9-month revolution” (Tomasello, 1999). For all the challenges to this concept (including from this thesis), the notion of significant changes occurring at around 9 months of age has proved a remarkably persistent idea, from Tomasello’s use of “revolution,” to Stern’s (1985) “quantum leap,” to Piaget’s (1952) view that these changes were the “appearance of a stage: that of the first actually intelligent behaviour patterns” (p. 210). Trevarthen and Hubley (1978) went so far as to state, “A significant growth transformation of the infant mind at about 9 months has been detected by all who have made adequate biographic observations” (p. 214).

One response is simply that all of these researchers fell into various methodological traps. They have used insufficiently frequent sampling that creates the false impression of sudden developmental shifts (Adolph et al., 2008), have failed to use sufficiently fine-grained analysis that can reveal the gradual nature of changing behaviours (de Barbaro et al., 2013; 2016; Rossmanith et al., 2014) and have failed to adequately focus on the months leading up to 9 months (Striano & Bertin, 2005a, 2005b; Striano et al., 2009; see also Chapters 3 to 6). On the other hand, it seems puzzling that so many researchers, including those who have followed infants closely in the early months of their first year, have come to the conclusion that important changes occur at around 9 months. So there is a bind: on the one hand, a substantial body of research has now gone against the idea of a sudden shift taking place at around 9 months. And yet, a long tradition of researchers have identified that *something* seems to change during this developmental period.

The idea of a rapid shift was also highlighted by some of the mothers taking part in the study. Consider the following quotations, collected during the maternal interviews that took place as part of this thesis. At the start of each interview, mothers were asked to give their general impressions of the previous weeks; they were not asked about any specific developments. In several cases, the mothers tried to articulate that something substantive had changed between 8 to 10 months:

> Participant 1, 10 months: "She's just hugely interactive... and kind of like really watching things, and exploring, but with more with intent I would say, everything's just got more intent behind it."
>
> Participant 3, 9 months: "…I definitely think she's changed, quite a bit… just in the last couple of weeks I feel that she's… she's becoming her own little person."
>
> Participant 14, 9 months: "We just joked that he like became a different person like last week, just much more... he wants things a certain way much more. He's less distractible. He's just more intense in his play I guess."
>
> Participant 21, 8 months: "Yeah, like yesterday she turned 8 months, and she's showing her mum something new... it's like she thought 'Oh I'm 8 months old now, I need to show it!'"
>
> Participant 26, 9 months: "In the last few days he suddenly got significantly older! But it happened to be in the few days after he had turned 9 months… He seems more independent and he seems a bit more interactive."

Caregivers often noted, at around 9 months (though ranging from 8 to 10 months), that a change had occurred in their child. However, quite what that change was what not clearly consistent across mothers, even with some consistent themes, such as the infants' capacity to interact and a sense of independence on the part of the infant. It is also pertinent that mothers sometimes explicitly highlighted the gradual nature of these changes, for example:

> Participant 18, 9 months: [Discussing changes in her infant's interaction] "It's something that's been building up I think over the past, I don't know, maybe couple of months. I think the last time that we went through everything he was definitely more interactive then, and yeah he's just building up from there."

It seems that what is needed is a different way to approach the notion of the 9-month revolution, one that does not focus on a singular shift in any particular cognitive ability (Tomasello, 1999), one that can pull together the apparently diverse ways in which infants are changing and developing at this age. Despite broad similarities in sociocognitive abilities across diverse cultures by 1 year of age (Callaghan et al., 2011; Liszkowski et al., 2012), to look for an ability or set of abilities that might change suddenly at around 9 months across all infants across all cultures seems, based on current evidence, destined for failure.

Rather than focusing on a sudden shift in cognitive capacity, the focus could instead shift to infants' shifting *social role*. This requires focusing more on interpretive frameworks or narratives used to make sense of infants' development, and focusing on changes in infants' confidence and competence. Here, the work of Bruner on "narrative" is instructive (1986, 1990). For Bruner, narrative constitutes way of making sense of behaviour, pulling together disparate behaviours into meaningful wholes and providing an ordered structure. It is not simply referring to a use of language; indeed, Bruner (1990) argued that "Narrative structure is even inherent in the praxis of social interaction before it achieves linguistic expression" (p. 77). As argued earlier in this chapter, humans do not make sense of others' behaviour solely in terms of sets of categorisable features, but in wholes that are interpreted in meaningful ways.

An analogy can be drawn with motor development. Consider the differences between researchers' identification of the gradual developments that precipitate infants' capacity to engage in increasingly controlled forms of bipedal locomotion (Adolph et al., 2003; 2018; Adolph & Tamis-Lemonda, 2014) and caregivers' recordings of their infants' "first steps." The former approach charts gradually occurring changes across multiple motor abilities; the latter represents a narratively significant moment, with a later, further narratival shift from "non-walker" to "walker." When an infant's "first steps" occur, they have not yet shifted from non-walker to walker, but this narratival marking point constitutes the first evidence that the infant is starting to make this transition in role. What exactly constitutes a "walker" may also depend on the interpretative framework of the caregiver; some may accept the stumbling toddler as a walker, whilst others may focus on confident walking even on complex terrain.

The argument is that there is a similar interpretive process for the social and cognitive developments observed in infants' first year. As the infant undergoes a range of gradual shifts in different social abilities, caregivers' social expectations of their infant change, as do their beliefs about what their infant is capable of doing. Whilst these may be registered as gradual changes, they may occur instantaneously or suddenly, as the previous examples indicate. Just as caregivers might register narratively significant moments such as "first steps," so they can experience a particular interactive episode that generates a shift in how they view their infant from then onwards; from dependent to independent, from socially uninterested to interactively engaged and ultimately newly communicative. It may be that, like walking, these interactive encounters only mark the start of a shift in social role from non-communicator to communicator; the first evidence of a change that only comes to fruition as several more of these encounters have occurred.

It is also plausible that differing interpretative frameworks applied by different cultures would mean that caregivers in other cultures do not experience their infants as rapidly changing in the same manner as Western caregivers can do. For example, if there is less of a prioritisation of frequent social engagement with infants or even the active avoidance of social engagements (Gottlieb, 2004; Keller, 2013), it may well be that there is no such experience of the infant taking on a new social role at around 9 months. Again, the cross-cultural research is a necessity. Only through it can we establish when different social abilities emerge across cultures, how these developments are understood within the interpretive frameworks of these cultures, and how the interplay between the infants' changing abilities and caregivers responses to these abilities unfolds across different cultures.

One might ask where the infant is in this process. It is important to stress that these developments are not only taking place in the perception of caregivers, but that the infant is still undergoing important developments. This thesis has highlighted a sense of shifting "confidence" or "competence" on the part of the infant: not a kind of metacognitive awareness, but some sense of changing willingness or motivation to employ social abilities that may have previously only emerged in a genuine but fragile form. The case of joint attention looks is one such example; they might start to appear as young as 6 months, or even earlier (and be genuine instances of joint attention looks), but the infant only later (at around 9 to 10 months) uses them consistently and flexibly. The process of becoming more consistent and flexible is one that gives the infant greater confidence (broadly construed) in her capacity to initiate new social situations, which in turn contributes to the perception of the infant as communicator in the narrative framework of the caregiver. These shifts are thus part of the reciprocal, dynamic nature of infant-caregiver social encounters; both interaction partners are negotiating how the shifting social capacities of the infant create new social situations and expectations.

This approach requires not only focusing on particular social or cognitive abilities, and into the murky world of social roles, narratives and interpretive frameworks. However, this does not make it beyond the scope of empirical enquiry. Focusing on caregivers, if there are narratival shifts, one would expect this to play a role in social development. There is already evidence that infants take an increasingly initiating role at around 9 months (Cohn & Tronick, 1987; de Barbaro et al., 2013), though a shift simply from "responder" to "initiator" appears to be insufficiently conceptually dense to fully capture how these changes are perceived, particularly as infants already can initiate intersubjective engagements from earlier in infancy (Reddy, 2010). Chapter 7 highlighted the range of possible methods that can be used to examine caregiver understanding and interpretation. Implicit beliefs can be inferred from interviews (e.g. Degotardi et al., 2008) and from observations of behaviour in interactions (e.g. Meins, 1997; Shai & Meins, 2018). Explicit beliefs can be articulated through interviews and questionnaires (e.g. Eadie et al., 2010; Fenson et al., 1994), or from watching video recordings and asking for participants' views (e.g. Adamson et al., 1987; Graham et al., 2021; Zeedyk, 1997). These methods can all be used to build a picture of shifting interpretations and narratives across infants' first year, and how this might play out in the context of caregiver-infant interactions.

Focusing on the infants, this study has presented evidence for growing frequency of production of joint attention looks, but this approach could be broadened out to other social abilities. However, there is a need for further conceptual discussion of how precisely to identify a change in confidence or competence. Whilst consistent and flexible usage across contexts provides one indirect measure, it is not clear what degree of confidence might be sufficient to have cascading effects on caregiver-infant interactions. Furthermore, it may be beneficial to examine other effects of shifting confidence or awareness. For example, it has been suggested that stranger anxiety (Ainsworth et al., 1978) in Western infants occurs due, in part, because non-caregivers do not always understand the communicative efforts of the infant (Trevarthen & Aitken, 2001). Ultimately, the challenge is to unpick the complex system of interacting developments that occur across infants' first year in order to more clearly understand how different developments are connected. This challenge again highlights the necessity of research with socially, culturally and economically diverse populations, for whom the system of developments may unfold in substantially different ways (Henrich et al., 2010; Nielsen et al., 2017).

8.3 Conclusion

The thesis began by highlighting the intertwined questions of the definition and development of joint attention. This thesis has addressed both issues, providing new data, methods and conceptual discussion that progress our understanding of the developmental origins of joint attention. In particular, it has built on previous accounts that emphasise the necessity of understanding the issue of the jointness of joint attention, and the role of communication (e.g. Carpenter & Liebal, 2011; Hobson & Hobson, 2007; Hobson, 2005; Siposova & Carpenter, 2019). Looking forward, it has highlighted the importance of continuing to develop novel approaches to eliciting joint attention abilities, as well as drawing upon different kinds of data and employing different kinds of methods. It has also stressed the importance of further examining the abilities, processes and interactions that precede the important changes in joint attention and communication that occur across infants' first year, which can provide a deeper understanding of the developmental roots of these abilities.

It was highlighted in the introduction that joint attention is widely recognised as an important ability. This is now not only the case in developmental psychology, but in a range of domains related to human cognition, sociality and culture (Eilan et al., 2005; Seemann, 2011; Tomasello, 2019; Tomasello et al., 2005; Veissière et al., 2020). Yet, whilst joint attention has proved an important concept in different areas of research, understanding how it develops remains an essential issue, one that can continue to inform other domains of investigation. Thus, as our understanding of the development and definition of joint attention is deepened, so too is our understanding of human cognition, sociality and culture.

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APPENDICES

Appendix 1

Ethical approval documents, including the original application and late amendments.

University of St Andrews | FOUNDED 1413

University Teaching and Research Ethics Committee

12 November 2018

Dear Gideon

Thank you for submitting your ethical application which was considered at the School of Psychology & Neuroscience Ethics Committee meeting on 1st November 2018; the following documents have been reviewed:

1. Ethical Application Form
2. Procedure
3. Study Advertisement: Email, In the Loop, Student Memos, Poster, Facebook
4. Database Sign-up Advertisement: Poster
5. Participant Information Sheet
6. Participant Consent Form
7. Participant Debriefing Form
8. Questionnaire: Infant Behaviour Questionnaire: Revised
9. Data Management Plan
10. PVG Scheme Record

The School of Psychology & Neuroscience Ethics Committee has been delegated to act on behalf of the University Teaching and Research Ethics Committee (UTREC) and has granted this application ethical approval. The particulars relating to the approved project are as follows -

Approval Code:	PS13951	**Approved on:**	01/11/2018	**Approval Expiry:**	01/11/2023
Project Title:	The Development of Communication and Joint Attention				
Researcher:	Gideon Salter				
Supervisor:	Professor Malinda Carpenter				

Approval is awarded for five years. Projects which have not commenced within two years of approval must be re-submitted for review by your School Ethics Committee. If you are unable to complete your research within the five year approval period, you are required to write to your School Ethics Committee Convener to request a discretionary extension of no greater than 6 months or to re-apply if directed to do so, and you should inform your School Ethics Committee when your project reaches completion.

If you make any changes to the project outlined in your approved ethical application form, you should inform your supervisor and seek advice on the ethical implications of those changes from the School Ethics Convener who may advise you to complete and submit an ethical amendment form for review.

Any adverse incident which occurs during the course of conducting your research must be reported immediately to the School Ethics Committee who will advise you on the appropriate action to be taken.

Approval is given on the understanding that you conduct your research as outlined in your application and in compliance with UTREC Guidelines and Policies (http://www.st-andrews.ac.uk/utrec/guidelinespolicies/). You are also advised to ensure that you procure and handle your research data within the provisions of the Data Provision Act 1998 and in accordance with any conditions of funding incumbent upon you.

Yours sincerely

Convener of the School Ethics Committee   cc   Professor Malinda Carpenter (Supervisor)

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

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University Teaching and Research Ethics Committee

19 December 2018

Dear Gideon

Thank you for submitting your amendment application which comprised the following documents:

1. Ethical Amendment Application Form
2. Participant Information Sheet

The School of Psychology & Neuroscience Ethics Committee is delegated to act on behalf of the University Teaching and Research Ethics Committee (UTREC) and has approved this ethical amendment application. The particulars of this approval are as follows –

Original Approval Code:	PS13951	**Approved on:**	01/11/2018
Amendment Approval Date:	13/12/2018	**Approval Expiry Date:**	01/11/2023
Project Title:	The Development of Communication and Joint Attention		
Researchers:	Gideon Salter, Kaja Andersen, Madalina Manoliu and Sally Johnson		
Supervisor:	Professor Malinda Carpenter		

Ethical amendment approval does not extend the originally granted approval period of five years, rather it validates the changes you have made to the originally approved ethical application. If you are unable to complete your research within the original five year validation period, you are required to write to your School Ethics Committee Convener to request a discretionary extension of no greater than 6 months or to re-apply if directed to do so, and you should inform your School Ethics Committee when your project reaches completion.

Any serious adverse events or significant change which occurs in connection with this study and/or which may alter its ethical consideration, must be reported immediately to the School Ethics Committee, and an Ethical Amendment Form submitted where appropriate.

Approval is given on the understanding that you adhere to the 'Guidelines for Ethical Research Practice' (http://www.st-andrews.ac.uk/media/UTRECguidelines%20Feb%2008.pdf).

Yours sincerely

Convener of the School Ethics Committee

cc Professor Malinda Carpenter (Supervisor)

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

The University of St Andrews is a charity registered in Scotland: No SC013532

University of St Andrews | FOUNDED 1413

University Teaching and Research Ethics Committee

29 April 2019

Dear Gideon

Thank you for submitting your amendment application which comprised the following documents:

1. Ethical Amendment Application Form
2. Participant Information
3. Consent Form

The School of Psychology & Neuroscience Ethics Committee is delegated to act on behalf of the University Teaching and Research Ethics Committee (UTREC) and has approved this ethical amendment application. The particulars of this approval are as follows –

Original Approval Code:	PS13951	Approved on:	01/11/2018
Amendment Approval Date:	24/04/2019	Approval Expiry Date:	01/11/2023
Project Title:	The Development of Communication and Joint Attention		
Researchers:	Gideon Salter		
Supervisor:	Professor Malinda Carpenter		

Ethical amendment approval does not extend the originally granted approval period of five years, rather it validates the changes you have made to the originally approved ethical application. If you are unable to complete your research within the original five-year validation period, you are required to write to your School Ethics Committee Convener to request a discretionary extension of no greater than 6 months or to re-apply if directed to do so, and you should inform your School Ethics Committee when your project reaches completion.

Any serious adverse events or significant change which occurs in connection with this study and/or which may alter its ethical consideration, must be reported immediately to the School Ethics Committee, and an Ethical Amendment Form submitted where appropriate.

Approval is given on the understanding that you adhere to the 'Guidelines for Ethical Research Practice' (http://www.st-andrews.ac.uk/media/UTRECguidelines%20Feb%2008.pdf).

Yours sincerely

Convener of the School Ethics Committee

Cc Professor Malinda Carpenter (Supervisor)

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

The University of St Andrews is a charity registered in Scotland: No SC013532

University of St Andrews | FOUNDED 1413

School of Psychology & Neuroscience Ethics Committee

13 February 2020

Dear Gideon

Thank you for submitting your ethical amendment application.

The School of School of Psychology & Neuroscience Ethics Committee has approved this ethical amendment application:

Original Approval Code:	PS13951	**Original Approval Date:**	01/11/2018
Amendment Approval Date:	04/02/2020	**Approval Expiry Date:**	01/11/2023
Project Title:	The Development of Communication and Joint Attention		
Researcher:	Gideon Salter	**Supervisor/PI:**	Prof Malinda Carpenter
School/Unit:	School of Psychology & Neuroscience		

This approval does not extend the originally granted approval period. If you require an extension to the approval period, you can write to your School Ethics Committee who may grant a discretionary extension of no greater than 6 months. For longer extensions, or for any further changes, you must submit an additional ethical amendment application. For all extensions, you should inform the School Ethics Committee when your study is complete.

You must report any serious adverse events, or significant changes not covered by this approval, related to this study immediately to the School Ethics Committee.

Approval is given on the following conditions:

- that you conduct your research in line with:
  - the details provided in your ethical amendment application (and the original ethical application where still relevant)
  - the University's Principles of Good Research Conduct
  - the conditions of any funding associated with your work

Cont.

School of Psychology & Neuroscience Ethics Committee
Shona Deigman, Convenor
School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife, KY16 9JP
Telephone: 01334 462071 Email: psyethics@st-andrews.ac.uk
The University of St Andrews is a charity registered in Scotland: No SC013532

- that you obtain all applicable additional documents (see the relevant webpage for guidance) before research commences.

You should retain this approval letter with your study paperwork.

Yours sincerely,

Shona Deigman
Convenor of the School Ethics Committee

cc. Prof Malinda Carpenter

School of Psychology & Neuroscience Ethics Committee
Shona Deigman, Convenor
School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife, KY16 9JP
Telephone: 01334 462071 Email: psyethics@st-andrews.ac.uk
The University of St Andrews is a charity registered in Scotland: No SC013532

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School of Psychology & Neuroscience Ethics Committee

16 September 2020

Dear Gideon

Thank you for submitting your ethical amendment application.

The School of School of Psychology & Neuroscience Ethics Committee has approved this ethical amendment application:

Original Approval Code:	PS13951	Original Approval Date:	01/11/2018
Amendment Approval Date:	31/08/2020	Approval Expiry Date:	01/11/2023
Project Title:	The Development of Communication and Joint Attention		
Researcher(s):	Gideon Salter, Professor Malinda Carpenter and Research Assistants (list held on file)		
Supervisor/PI:	Professor Malinda Carpenter		
School/Unit:	School of Psychology & Neuroscience		

This approval does not extend the originally granted approval period. If you require an extension to the approval period, you can write to your School Ethics Committee who may grant a discretionary extension of no greater than 6 months. For longer extensions, or for any further changes, you must submit an additional ethical amendment application. For all extensions, you should inform the School Ethics Committee when your study is complete.

You must report any serious adverse events, or significant changes not covered by this approval, related to this study immediately to the School Ethics Committee.

Approval is given on the following conditions:

- that you conduct your research in line with:
    - the details provided in your ethical amendment application (and the original ethical application where still relevant)
    - the University's Principles of Good Research Conduct
    - the conditions of any funding associated with your work
- that you obtain all applicable additional documents (see the relevant webpage for guidance) before research commences.

Cont.

School of Psychology & Neuroscience Ethics Committee
Shona Deigman, Convenor
School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife, KY16 9JP
Telephone: 01334 462071 Email: psyethics@st-andrews.ac.uk
The University of St Andrews is a charity registered in Scotland: No SC013532

You should retain this approval letter with your study paperwork.

Yours sincerely,

Helen Sunderland
Administrator of the School Ethics Committee

cc. Professor Malinda Carpenter

Appendix 2A

Example Stimulus Set for One Session

Each item is photographed with a 15cm ruler for scale.

Figure 2A1. Large toys. Used in show elicitation, out of reach object, means-ends, and social reach tasks.

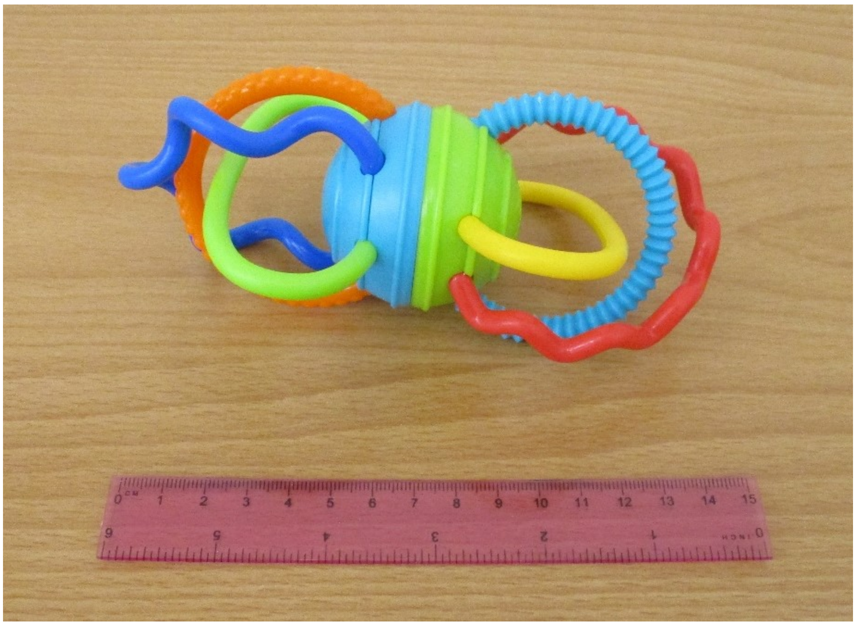


Figure 2A2. Small toys. Used in object permanence and give elicitation tasks.

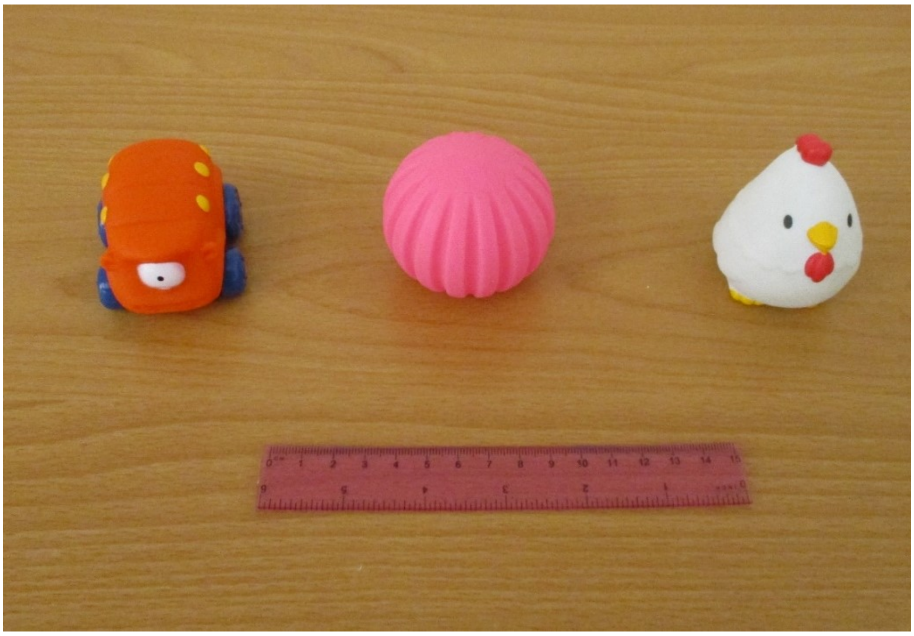


Figure 2A3. Xylophone. Used in interesting sound joint attention look elicitation task.

Figure 2A4. Hinge. Used in triadic imitation task.

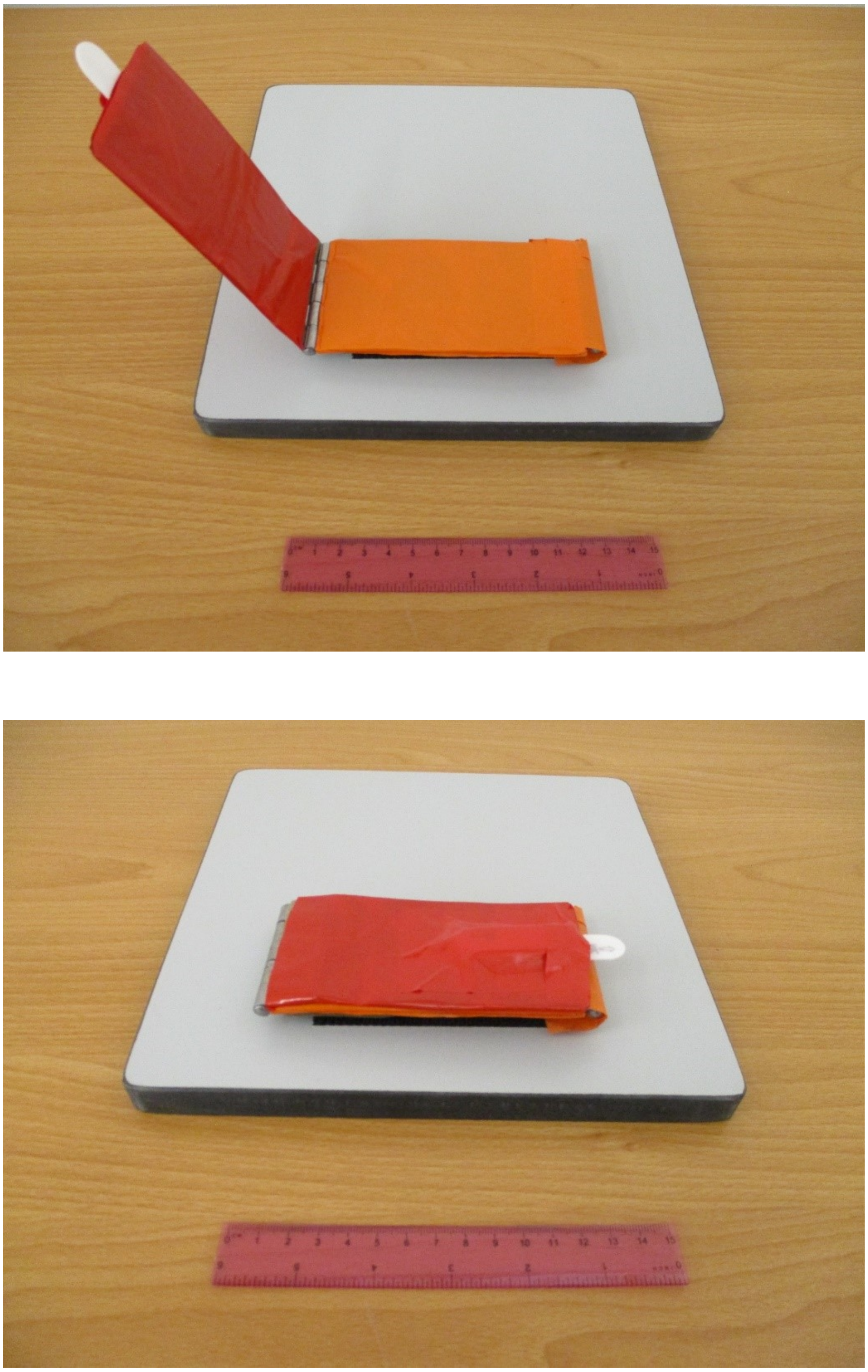


Figure 2A5. Transparent box. Used in transparent box task.

Figure 2A6. Flashing light box. Used in interesting sight joint attention look elicitation task.

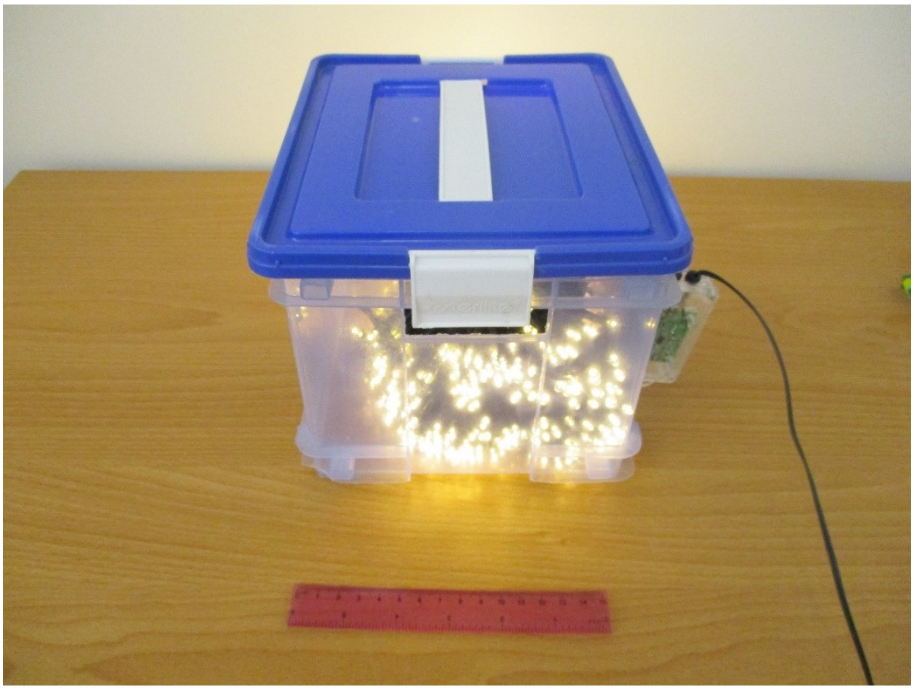


Figure 2A7. Stacking cups. Used in cup tower activity.

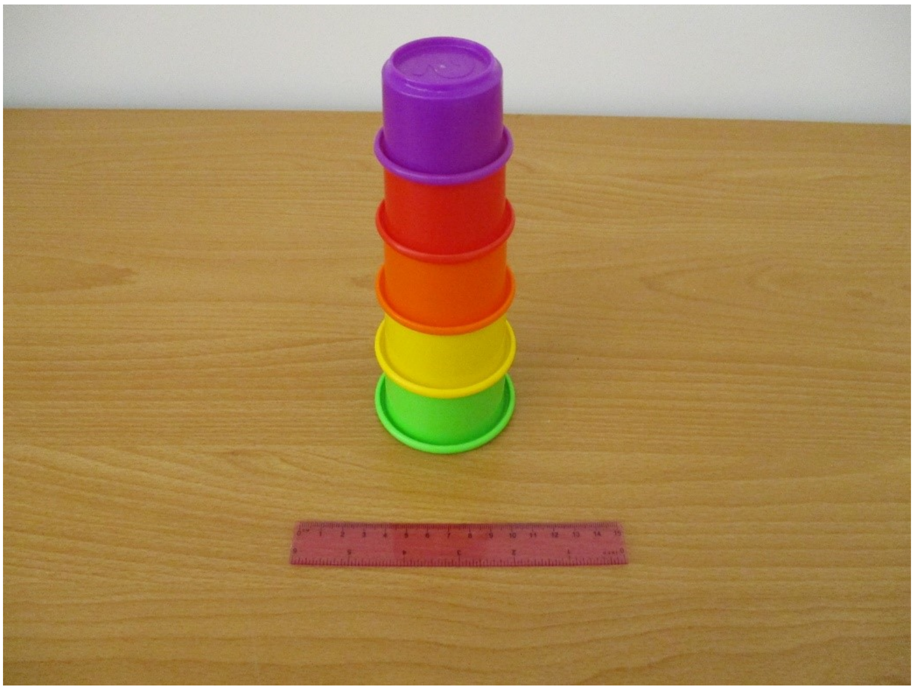


Figure 2A8. Remote-controlled dinosaur. Used in moving toy joint attention look elicitation task.

Figure 2A9. 42 x 69cm cloth. Used in means-end and object permanence tasks.

Figure 2A10. Large stuffed toys. Used in gaze and point following tasks.

Figure 2A11. Free play stimuli.


Puppy's Bedtime
Love my baby
from igloo


stripychus
(stripy-cuss)

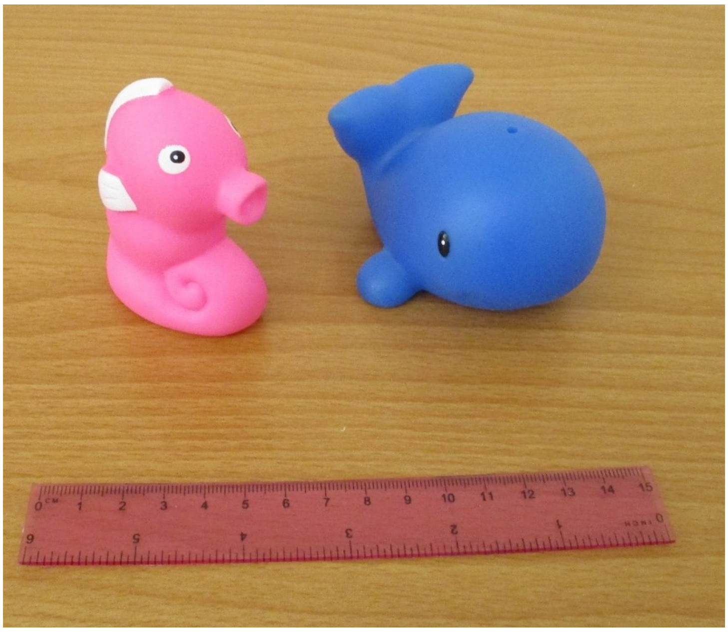


Figure 2A12. Decorated room stimuli.

Appendix 2B

Inter-Rater Reliability

Table 2B1. Reliability scores for each behaviour type.

Behaviour	Cohen's Kappa Coefficient (*κ*)	Agreement (%)
Joint attention looks	0.72	73.0
Giving gestures	0.86	84.6
Showing gestures	0.66*	81.5
Pointing gestures	0.35*	74.1
Gaze following	0.74	77.3
Point following	0.75	73.1
Means end understanding	0.75	81.4
Object permanence understanding	0.80	83.7
Imitation	0.77	87.7
Independent sitting	0.85	83.1
Self-locomotion	0.90	84.5
Interview, joint attention looks	0.62**	57.8
Interview, showing gestures	0.92	92.0
Interview, independent sitting	0.72	84.4
Interview, self-locomotion	0.91	86.9

Note. *κ score below 0.7 threshold. In these cases, a third coder resolved different scores. It is worth noting that cases with high percentage agreement but low κ are those with a large number of "0" scores in the dataset, which means that instances in which a "1" or "2" were awarded had a large amount of leverage on the κ score. **Due to time limitations, differences were not resolved, meaning the expert coder scores were used. Because of the length of time required to code from free play, 33% of free play cases were coded. This included joint attention looks, showing gestures and pointing gestures. For interview coding of joint attention looks, 50% of cases were coded due to the time limitations.

Appendix 3A

Task Stimuli

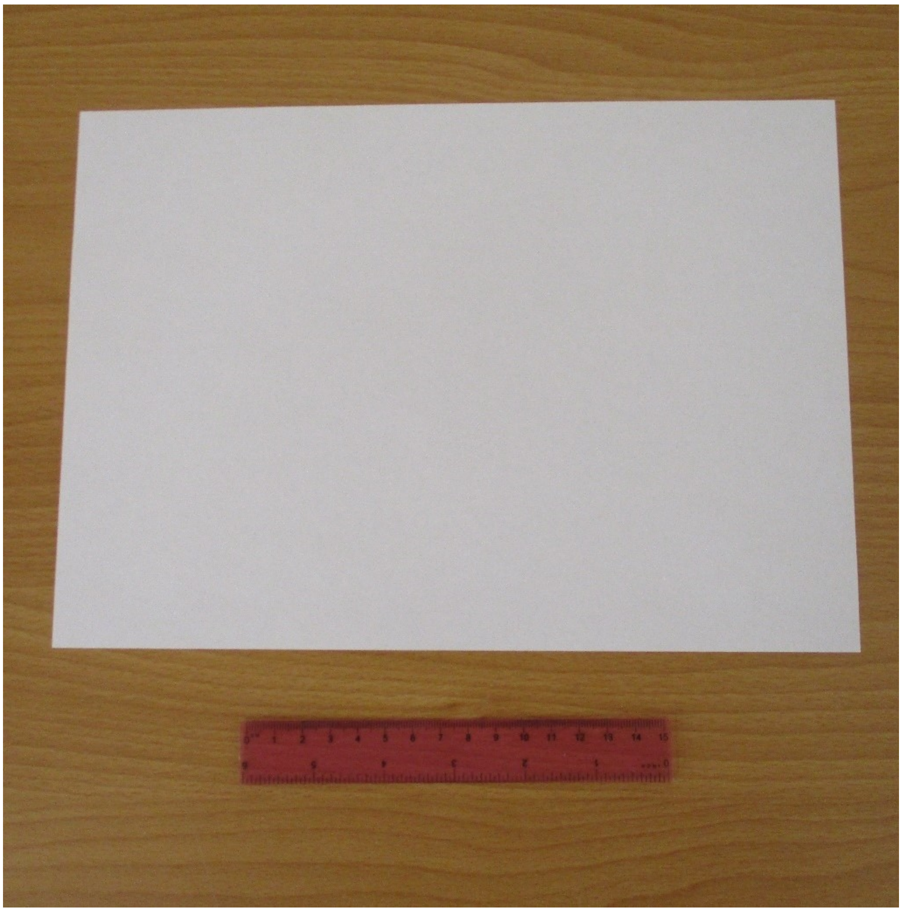
Figure 3A1. Light box used in the Interesting Sight task, with a 15cm ruler for scale.

Figure 3A2. Remote-controlled toys used in the Moving Toy task, with a 15cm ruler for scale. In order: R/C dinosaur, R/C turtle, R/C robot dog, R/C robot chameleon and R/C humanoid robot.


CATCHING
IN PROGRESS
RCX-01
OFF
ON


06
AGENT

Figure 3A3. Stimuli used in the Interesting Sound task. In order: a "Groan tube" that produces a sound when inverted, a xylophone that produces notes when struck, a "Moo tube" that produces a sound when inverted, a toy that clicks when twisted, and a A4 sheet of paper that was manipulated to produce a noise.

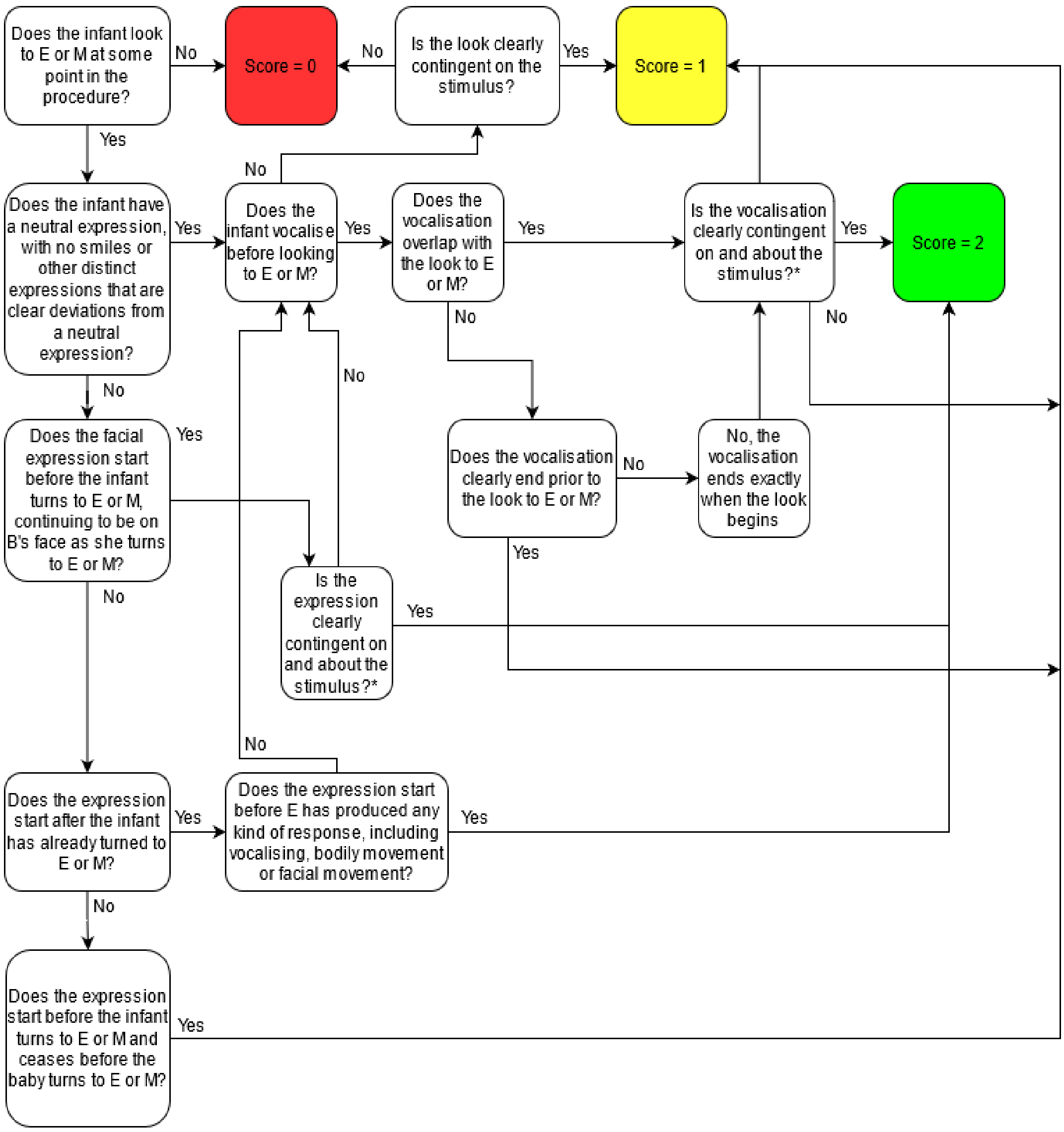


Appendix 3B

Behavioural Coding of Joint Attention Looks

Note that "E" refers to experimenter, and "M" refers to mother.

Figure 3B1. Logic diagram for behavioural coding of joint attention looks.



Further points of guidance

Is the behaviour clearly* contingent on *and* about *the stimulus? The behaviour needs to occur immediately after the infant has attended to the stimulus. It needs to be clear that the infant was not playing with some other object or the table, which might be what they were reacting to instead of the stimulus. The length of time before the look does not matter: it is acceptable for the infant to stare continually at the stimulus for any length and then look to E or M.

Previously performed behaviours. If any of the behaviours, whether vocalisations or expressions, are clearly present prior to the start of the task phase, consider whether the behaviours, if occurring alongside looking behaviours, are in fact clearly distinct communicative acts about the stimulus, or are just continuations of the same behaviour.

Resetting between phases: Each task involves the stimulus being activated three times (sound made, light box on, moving toy activated). Each activation "resets" the coding scheme (i.e., previous responses from E do not delegitimise the response). Resets can also occur if the child has looked to E, reacted, and then ends up looking back to the stimulus. The main condition is that they are clearly reacting to the stimulus.

Looks to face. As long as the looks are clearly identifiable as being to E's or M's face, they count. It does not matter if they are brief.

Free play. In free play, particular care needs to be paid to whether the response was in response to the activity of the mother. If it is not clear, code conservatively and score a "0". It must also be clear what the target of the joint attention look is, such as a toy or the noise made by a toy. If it is not clear, code conservatively and score a "0".

Appendix 3C

Tables of Model Coefficients

A few notes of guidance on interpreting the tables in this section:

- The intercept may include both age (6 months) and one of the other categorical dependent variables, which is why these do not have their own row.
- Odds ratios are a measure of association between an exposure and a dichotomous outcome (Szumilas, 2010). For interpretational simplicity, it suffices to say here that values of >1 can be interpreted as there being a higher odds of the "1" outcome occurring (e.g., successful production of joint attention look) compared to the "0" outcome. Larger values above 1 indicate greater odds of that event occurring for that particular exposure (e.g. task type or age).
- SE refers to the standard error.
- CI refers to the 95% confidence interval for the odds ratios.
- R^2 values quantify the goodness-of-fit of a model. In the case of mixed models, two types of R^2 can be computed. Marginal R^2 quantifies the variance explained by fixed effects only, while conditional R^2 quantifies the variance explained by both fixed and random effects (Nakagawa & Schielzeth, 2013).

Table 3C1. Output of GLMM in section 3.2.1 modelling production of joint attention looks across all tasks.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.77	0.34	0.33 – 1.82	0.55
Age (7 months)	1.42	0.84	0.44 – 4.56	0.56
Age (8 months)	5.80	3.97	1.51 – 22.20	0.010*
Age (9 months)	4.53	2.98	1.25 – 16.45	0.022*
Age (10 months)	16.25	14.28	2.90 – 90.98	0.002**
Observations	124			
Marginal R^2 / Conditional R^2	0.216 / 0.294			

Note. *p < 0.05, **p < 0.01.

Table 3C2. Output of GLMM in section 3.2.1 modelling production of joint attention looks across the experimental tests.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.05	0.04	0.01 – 0.28	0.001**
Age (7 months)	1.00	1.10	0.12 – 8.55	1.000
Age (8 months)	4.59	4.36	0.71 – 29.50	0.109
Age (9 months)	15.25	14.67	2.31 – 100.53	0.005**
Age (10 months)	16.30	15.75	2.45 – 108.29	0.004**
Observations	124			
Marginal R^2 / Conditional R^2	0.237 / 0.492			

Note. **p < 0.01.

Table 3C3. Output of GLMM in section 3.2.1 modelling production of joint attention looks in the free play.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.66	0.28	0.29 – 1.50	0.322
Age (7 months)	1.65	0.96	0.53 – 5.14	0.390
Age (8 months)	4.00	2.48	1.18 – 13.49	0.026*
Age (9 months)	2.74	1.63	0.85 – 8.81	0.091
Age (10 months)	7.82	5.49	1.98 – 30.93	0.003**
Observations	124			
Marginal R^2 / Conditional R^2	0.129 / 0.157			

Note. *$p < 0.05$, **$p < 0.01$.

Table 3C4. Output of GLMM in section 3.2.2 modelling production of joint attention looks, experimental procedures versus free play.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.11	0.04	0.05 – 0.24	<0.001***
Age (7 months)	1.42	0.69	0.55 – 3.68	0.469
Age (8 months)	3.56	1.70	1.40 – 9.07	0.008**
Age (9 months)	4.76	2.29	1.85 – 12.24	0.001**
Age (10 months)	8.06	4.02	3.03 – 21.43	<0.001***
Task Type (Experimental)	5.88	1.83	3.19 – 10.82	<0.001***
Observations	248			
Marginal R^2 / Conditional R^2	0.293 / 0.302			

Note. **$p < 0.01$, ***$p < 0.001$. Task Type was a categorical variable with two levels, “Free Play” (reference category) and “Experimental.”

Table 3C5. Output of GLMM in section 3.2.2 modelling production of joint attention looks, experimental procedures versus free play, with an interaction between age and task type.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.09	0.06	0.02 – 0.37	0.001**
Age (7 months)	1.00	1.04	0.13 – 7.74	1.000
Age (8 months)	3.66	3.21	0.66 – 20.38	0.138
Age (9 months)	9.20	7.77	1.76 – 48.16	0.009**
Age (10 months)	9.87	8.37	1.88 – 51.96	0.007**
Task Type (Experimental)	7.79	6.59	1.48 – 40.94	0.015*
Age (7 months)* Task Type (Experimental)	1.63	1.95	0.16 – 16.92	0.680
Age (8 months)* Task Type (Experimental)	1.07	1.14	0.13 – 8.65	0.949
Age (9 months)* Task Type (Experimental)	0.29	0.30	0.04 – 2.20	0.233
Age (10 months)* Task Type (Experimental)	0.77	0.84	0.09 – 6.54	0.813
Observations	248			
Marginal R^2 / Conditional R^2	0.328 / 0.338			

Note. *$p < 0.05$, **$p < 0.01$. Task Type was a categorical variable with two levels, “Free Play” (reference category) and “Experimental.”

Table 3C6. Output of GLMM in section 3.2.3 modelling production of joint attention looks in each of the experimental tests and free play.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.15	0.05	0.08 – 0.30	<0.001***
Age (7 months)	1.20	0.45	0.58 – 2.49	0.620
Age (8 months)	2.43	0.84	1.23 – 4.81	0.011*
Age (9 months)	3.06	1.05	1.56 – 6.00	0.001**
Age (10 months)	4.15	1.43	2.11 – 8.15	<0.001***
Task Type (Interesting Sight)	1.81	0.52	1.03 – 3.19	0.040*
Task Type (Interesting Sound)	0.92	0.28	0.51 – 1.68	0.796
Task Type (Moving Toy)	1.58	0.46	0.90 – 2.79	0.114
Observations	493			
Marginal R^2 / Conditional R^2	0.099 / 0.132			

Note. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Task Type was a categorical variable with four levels, “Free Play” (reference category), “Interesting Sight”, “Interesting Sound” and “Moving Toy.”

Table 3C7. Output of GLMM in section 3.2.4 modelling consistency of production of joint attention looks.

	Combined Joint Attention Look Score			
Predictors	Incidence Rate Ratios	SE	CI	*p*
(Intercept)	0.68	0.16	0.42 – 1.09	0.112
Age (7 months)	1.18	0.39	0.62 – 2.25	0.622
Age (8 months)	1.94	0.58	1.08 – 3.48	0.026*
Age (9 months)	2.24	0.65	1.26 – 3.96	0.006**
Age (10 months)	2.63	0.75	1.50 – 4.62	0.001**
Observations	124			
Marginal R^2 / Conditional R^2	0.190 / NA			

Note. **p* < 0.05 ***p* < 0.01. Incidence rate ratio is interpreted similarly to an odds ratio, with higher scores indicating a higher likelihood.

Table 3C8. Output of GLMM in section 3.2.5 modelling production of intentional social looks in each of the experimental tests and free play.

	Intentional Social Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	1.16	0.36	0.64 – 2.12	0.623
Age (7 months)	1.82	0.67	0.89 – 3.73	0.104
Age (8 months)	3.79	1.60	1.66 – 8.69	0.002**
Age (9 months)	5.71	2.69	2.27 – 14.38	<0.001***
Age (10 months)	4.05	1.77	1.72 – 9.52	0.001**
Task Type (Interesting Sight)	3.51	1.34	1.67 – 7.40	0.001**
Task Type (Interesting Sound	15.41	9.69	4.49 – 52.85	<0.001***
Task Type (Moving Toy)	1.50	0.48	0.80 – 2.81	0.206
Observations	494			
Marginal R^2 / Conditional R^2	0.310 / 0.325			

Note. $**p < 0.01$, $***p < 0.001$. Task Type was a categorical variable with four levels, "Free Play" (reference category), "Interesting Sight", "Interesting Sound" and "Moving Toy."

Appendix 3D

Model Selection

Table 3D1. Corrected Akaike Information Criterion (AICc) scores for GLMs and GLMMs and their relative weighting.

Model Description	GLM AICc	GLM Weight	GLMM AICc	GLMM Weight
Production of Joint Attention Looks Across all Tasks (Table 3C1)	172.6	0	147.2	1
Production of Joint Attention Looks Across the Experimental Tests (Table 3C2)	195.2	0	164.8	1
Production of Joint Attention Looks in Free Play (Table 3C3)	146.8	0	130.0	1
Production of Joint Attention Looks, Experimental Tests Versus Free Play (Table 3C4)	318.6	0	293.3	1
Production of Joint Attention Looks, Experimental Tests Versus Free Play, with Age*Task Interaction (Table 3C5)	325.0	0	298.1	1
Production of Joint Attention Looks in each of the Experimental Tests and Free Play (Table 3C6)	603.8	0.001	589.6	0.999
Consistency of Joint Attention Look Production across all Tasks (Table 3C7)	398.2	0	345.9	1

Production of Intentional Social Looks between all Tasks in each of the Experimental Tests and Free Play (Table 3C8)	382.3	0	365.8	1

Note. Corrected Akaike Information Criterion (AICc) scores provide a quantification of model fit, with lower scores indicating better fit. The “Weight” columns provide an indication of the extent to which the model is preferred by the model selection function. The summed values of all weights always equal 1, and the model with the largest value has the strongest weighting, indicating a model with a better fit. AICc and weighting calculations were performed by the model.sel function in the MuMIn package (Bartoń, 2015).

Appendix 4A

Behavioural Coding Schemes for Communicative Gestures

4A1. Giving gestures

- **2: A clear, intentional, communicative giving gesture.**
  - The child intentionally places the toy into E's hand and releases it such that the toy remains in E's hand.
  - The child visually attends to **both the toy and E** over the course of the process.
    - Here, the process is from the initial handling of the toy up until and immediately after the movement of interest.
    - The order of look to toy and E/M does not matter
    - The length of look to toy and E/M does not matter
- **1: An attempt at giving, partial give, or otherwise relevant behaviour that involves features of a giving gesture but is missing (a) key component(s). This code accounts for behaviours which may plausibly be considered a giving gesture, but cannot be confidently assigned as such.**
  - The child intentionally places the object onto E's hand, but does not release it.
  - The child releases the toy intentionally towards E's hand and the toy makes contact with E's hand, but does not remain in E's hand.
  - The child intentionally places the toy into E's hand and releases it, but does not look to E's face during the process.
- **0: No give or attempted/partial give.**
  - The child does not perform a give or attempted/partial give. Cases that count as 0 include:

        - Accidentally bashing the toy against E’s hand, or accidentally dropping the toy into M’s hand.
        - Pressing the toy against E’s arm.

4A2. Showing gestures

- **2: An intentional, communicative, recognisable show.**
    - Key components:
        - The child **intentionally raises** the toy **into the view of E/M**. Raised means that at least 1 of the child’s hands that is holding the toy must be raised to at least shoulder height, or higher.
            - This can be either up towards the face of E/M, or up and to one side, as long as the toy ends up within the line of sight of E/M, and as long as the infant is intentionally moving it into E’s/M’s view.
        - The child visually attends to **both the toy and E/M** over the course of the process.
            - Here, the process is from the initial handling of the toy up until and immediately after the movement of interest.
                - However, if the child looks away from the object between initial handling and subsequent action (e.g. raise), it is necessary for there to be another instance of visual attention to the object during the subsequent process (e.g. raising and lowering of the toy).
            - The order of look to toy and E/M does not matter
            - The length of look to toy and E/M does not matter
        - The toy is held with a sufficient degree of **control**:

        - The toy is held steady, intentionally in view of E/M, for at least 1 second. If the toy is brought into view but moved away within 1 second, a 2 cannot be awarded.
        - Or: the toy is shaken/rattled/moved, but the child intentionally ensures it remains raised and in view of E/M while this is happening.
    - Examples that do not count:
        - The child was already holding/waving the toy above shoulder height, and continues to do so when E arrives (would receive 0).
        - The child raises the toy to examine it or feel it (e.g. on his/her face) (would receive 0).
        - The child raises the toy to chew it (would receive 0).
        - The child presses the toy against M's upper body/face (would receive 0).
        - The toy is raised because it is resting on some other surface (e.g., M's leg) (would receive 0).
- **1: An attempt at showing, partial show, or otherwise relevant behaviour that involves features of a show but is missing (a) key component(s). This code accounts for behaviours which may plausibly be considered a show, but cannot be confidently assigned as such.**
    - The child **intentionally raises** the toy **into the view of E/M**. Raised here is slightly less strict than for a 2: at least 1 of the child's hands that is holding the toy must be raised to at least chest height, or higher.

- This can be either up towards the face of E/M, or up and to one side, as long as the toy ends up within the line of sight of E/M, and as long as the infant is intentionally moving it into E's/M's view.
- 1 can be awarded for cases where the child raises the toy, visually attends to both the toy and E/M holds it steady for at least 1 second, but it is below shoulder height.
- Examples that do not count
  - The child was already holding/waving the toy above shoulder height, and continues to do so when E arrives (would receive 0).
  - The child raises the toy to examine it or feel it (e.g. on his/her face) (would receive 0).
  - The child raises the toy to chew it (would receive 0).
  - The child presses the toy against M's upper body/face (would receive 0).

- Needed pattern of looks is missing: Other components (raised and steady) are present, but the child **does <u>not</u> attend to both the toy and E/M**. For example:
  - The child raises the toy and visually attends to E/M, but does not visually attend to the toy at all during the process
  - The child raises the toy and visually attends to it, but does not look to E/M.
- Toy is **not held steady** within E/M's view: Other components are present, but the child does not hold the toy with a sufficient degree of control, i.e. does not intentionally hold it within E/M's view. For example:

        - The toy is intentionally held steadily in E/M's view, but is moved away after less than 1 second, or the child sweeps the toy through the view of E/M, with the toy not remaining in that space.
        - Or: The toy is shaken/rattled/moved and passes into E/M's view, but does not remain consistently raised and in view of E/M.
- **0: No attempt at any relevant behaviour, or unintentionally appropriate movements. Any raise of the toy that is clearly not communicative.**
    - There is no interaction with the object.
    - The child engages solely with the object.
    - The child moves the toy but not towards E/M.
    - The child moves the toy on the floor but with no visual attention towards E/M.
    - The child pushes the object against M's mouth/face/arm/shoulder/upper body or raises it only to chew on it, examine it or feel it (e.g. on his/her face).

4A3. Request gestures

4A3.1. Proximal request- requesting help with an object within reach.

- **2: A clear, intentional, proximal request gesture**
    - Intentional presentation of box to E as a request for assistance
        - The infant pushes the box forwards towards E and releases it, removing both hands from the box.
        - The box must end up on E's side of the table; a slight push in front of the infant is not sufficient.
    - The infant visually attends to both the toy and E over the course of the process.

        - Here, the process is from immediately prior to the act (pushing the box to E and removing both hands) to immediately after.
        - The order of look to toy or E does not matter
        - The length of look to toy or E does not matter, as long as it is certain that the infant looked towards E.

- **1: An attempt at a proximal request gesture, a partial proximal request gesture, or otherwise relevant behaviour that involves features of a proximal request gesture but is missing (a) key component(s). This code accounts for behaviours which may plausibly be considered a proximal request gesture, but cannot be confidently assigned as such.**
    - For example:
        - Intentional but incomplete presentation of box to E as a request for assistance:
            - The infant intentionally pushes the box towards E, looks at both E and the box, but does not release the box with both hands.
            - The infant must visually attend to both the box and E (see 2 section).
        - The infant pushes the box to E, but it is not certain if it occurred intentionally. If it is clearly or likely pushed accidentally, it gets a 0.
            - The infant must visually attend to both the box and E (see 2 section).
        - The infant produces the appropriate gesture, but lacks the appropriate visual attention pattern.
            - The infant intentionally pushes the box to E and releases it, but does not look at E.

- **0: No attempt at requesting help with a proximal object.**
    - The infant engages with the box, but does nothing else.
    - The infant bashes the box without looking to both the box and E.
    - The infant accidentally pushes the box towards E.
    - The infant pushes the box onto the floor.

4A3.2. Distal request- requesting help to obtain an object that is out of reach

- **2: A clear, intentional, distal request gesture**
    - The infant produces an request gesture to request the target object. This can be either:
        - Social reach: Intentional extending of the arm towards the target object with an open-handed reach. The orientation of the palm (up, down, sideways) and the position of the fingers (held together, all outstretched, slightly curled, opening and closing) does not matter.
        - Open-hand point: Intentional extending of the arm towards the target object with an open-handed form. The hand shape must be held (i.e., not opening and closing)
        - Index point: Intentional extending of the arm with an extended index finger clearly pointed towards the target object.
    - The infant visually attends to both the toy and E/M over the course of the process.
        - Here, the process is from immediately prior to the act (social reach, point) to the retracting of the arm after the act.

        - The length of look to toy or E/M does not matter, as long as it is certain that the infant looked towards E/M.

- **1: An attempt at a distal request gesture, a partial distal request gesture, or otherwise relevant behaviour that involves features of a distal request gesture but is missing (a) key component(s). This code accounts for behaviours which may plausibly be considered a distal request [gesture], but cannot be confidently assigned as such.**
    - A **possible social reach** that does not have the clear form:
        - The infant has an extended reaching arm, but it is not clearly towards the target object.
        - The infant extends his/her arm towards the target object, but the form is not clearly that of a social reach. For example:
            - The fingers are curled into a fist.
            - The wrist is not held straight.
        - This must be accompanied by the appropriate pattern of visual attention.
    - A **possible point** that does not have the clear form:
        - The infant has an extended arm and index finger, but it is not clearly towards the target object.
            - **NOTE**: if the infant points to E/M, please note this in the comments
        - The infant extends his/her arm towards the target object, but the form is not clearly that of an index finger point. For example:
            - The index finger is partially extended.
            - The wrist is not held straight.

        - This must be accompanied by the appropriate pattern of visual attention.
    - Points only: The infant produces a clear, intentional point but without the appropriate visual attention patterns.
        - The pointing gesture itself is clear (see 2 section above), but the infant does not look to both E/M and the target object.
- **0: No attempt at requesting a distal object**
    - The infant quickly loses interest in the target object.
    - The infant only looks at target object.
    - The infant reaches towards the object, but with no look to E.
    - The infant vocalises towards the target object with no gesture.

4A4. Pointing gestures

- **2: Clear, intentional pointing gesture**
    - The child produces a pointing gesture towards a target object. This can be either:
        - Open-hand point: Intentional extending of the arm towards the target object with an open-hand, where the fingertips are extended towards the target. The hand shape must be held (i.e., not opening and closing)
        - Index point: Intentional extending of the arm with an extended index finger clearly pointed towards the target object.
    - The child visually attends to both the toy and E/M over the course of the process.
        - Here, the process is from immediately prior to the act (social reach, point) to the retracting of the arm after the act.

        - The length of look to toy or E/M does not matter, as long as it is certain that the child looked towards E/M.
- **1: An attempt at a pointing gesture, a partial pointing gesture, or otherwise relevant behaviour that involves features of a pointing gesture but is missing (a) key component(s). This code accounts for behaviours that may plausibly be considered a pointing gesture, but cannot be confidently assigned as such.**
    - A **possible open-hand point** that does not have the clear form:
        - The child has an extended reaching arm, but it is not clearly towards the target object.
        - The child extends his/her arm towards the target object, but the form is not clearly that of an open-hand point. For example:
            - The fingers are curled into a fist.
            - The wrist is not held straight.
        - This must be accompanied by the appropriate pattern of visual attention.
    - A **possible index point** that does not have the clear form:
        - The child has an extended arm and index finger, but it is not clearly towards the target object.
        - The child extends his/her arm towards the target object, but the form is not clearly that of an index finger point. For example:
            - The index finger is partially extended.
            - The wrist is not held straight.
        - This must be accompanied by the appropriate pattern of visual attention.

- **For index points only**: The child produces a clear, intentional index point but without the appropriate visual attention patterns.
    - The pointing gesture itself is clear (see 2 section above), but the child does not look to both E/M and the target object.

- **0: No attempt at a pointing gesture**
    - The child quickly loses interest in the target object.
    - The child only looks at target object.
    - The child reaches towards the object, but with no look to E.
    - The child vocalises towards the target object with no gesture.

Appendix 4B

Tables of Model Coefficients

See Appendix 3B for information regarding interpretation of model coefficient tables. It is important to note that for each of the following models, there are instances in which none of the participants produced the target behaviour for one or more of the months of interest. In these cases, the model coefficients are skewed by these data. This is particularly relevant when seeking to account for any significant increases between monthly scores. Whilst one solution would be to use multiple McNemar's tests instead of a GLMM (as done by, for example, Beuker and colleagues (2013)), this approaches ignores the dependence amongst scores within the same participant (which is accounted for by including participant as a random effect in GLMMs). Thus, the approach taken is as follows. First, the model is fit with all months included, and Tukey's test is used to assess differences between behaviour production in consecutive months. If there is a month with no participants producing the target behaviour followed by a month in which at least one participant producing the target behaviour, a McNemar's test is used to assess any significant difference between these months (with the *p* value corrected for multiple comparisons). This means that month-by-month comparisons are conducted with the dataset maintaining dependence within participants. For the purpose of displaying the model coefficients, the following tables take the approach of dropping any months with 0% or 100% behaviour production and fitting a model for the remaining months, in order to provide a model that is not warped by the 0% or 100% cases.

Table 4B1. Output of GLMM in section 4.2.1 modelling production of communicative gestures.

	Communicative Gesture Score			
Predictors	Log-Odds	SE	CI	*p*
(Intercept)	-4.72	1.83	-8.30 – -1.13	0.010*
Age (9 months)	2.80	1.51	-0.16 – 5.76	0.064
Age (10 months)	5.28	1.99	1.38 – 9.18	0.008**
Observations	74			
Marginal R^2 / Conditional R^2	0.396 / 0.723			

Note. *$p < 0.05$, **$p < 0.01$.

Table 4B2. Output of GLMM in section 4.2.3 modelling production of showing gestures.

	Show Score			
Predictors	Log-Odds	SE	CI	*p*
(Intercept)	-3.93	1.35	-6.57 – -1.28	**0.004**
Age (9 months)	2.04	1.23	-0.36 – 4.45	0.096
Age (10 months)	3.91	1.39	1.18 – 6.65	**0.005**
Observations	74			
Marginal R^2 / Conditional R^2	0.334 / 0.572			

Note. **$p < 0.01$.

Appendix 4C

Model Selection

Table 4C1. Corrected Akaike Information Criterion (AICc) scores for GLM and GLMM and relative weighting.

Model Description	GLM AICc	GLM Weight	GLMM AICc	GLMM Weight
Communicative Gestures (Table 4B1)	99.9	0	73.1	1
Showing Gestures (Table 4B2)	109.1	0	73.4	1

Note. See Table 3D1 for details on interpreting the model selection table.

Appendix 5A

Detailed Coding Schemes for Social, Cognitive and Motor Developments

5A1. Imitation

5.A1.1 Dyadic Imitation

For all cases, ensure that the target action was not performed prior to the demonstration of the action.

1. **Clap**

   2: The infant intentionally and successfully performs the target action: brings their hands together and apart at least once, with open palms.

   1: The infant unsuccessfully attempts the target action: brings hands together but holds them together without promptly bringing them apart; or brings hands together with closed palms.

   0: The infant makes no attempt at the target action.

2. **Open and close hands**

   2: The infant intentionally and successfully performs the target action: closes and then opens one or both hands at least once.

   1: The infant unsuccessfully attempts the target action: raises hands and moves hands, but not opening and closing at least one hand.

   0: The infant makes no attempt at the target action.

3. Hands on head

2: The infant intentionally and successfully performs the target action: raises hand(s) so the whole of at least one hand is positioned at the top of the infant's head. Anywhere above eye level counts; raising to forehead or top of head accepted.

1: The infant unsuccessfully attempts the target action: intentionally raises hand(s) towards their head, but not in contact with their head. Or, raises hand(s), but not so one or both are above eye level.

0: The infant makes no attempt at the target action.

4. Hands to cheeks

2: The infant intentionally and successfully performs the target action: raises their hand(s) and brings one or two palms into contact with their cheek(s).

1: The infant unsuccessfully attempts the target action: raises hand(s) near to their cheek(s), but no contact.

0: The infant makes no attempt at the target action.

5. Hands on table

2: The infant intentionally and successfully performs the target action: at least one hand intentionally placed on the table, palm(s) down, and held in place for at least 1 second.

1: The infant unsuccessfully attempts the target action: e.g., hand(s) banged intentionally on the table but not held in place.

0: The infant makes no attempt at the target action.

5.A1.2 Triadic Imitation

For all tasks, one or two hands can be used. In all cases, the infant must look at both the target object at some point during the process of performing the target action.

1. **Hinge**

   2: The infant intentionally and successfully performs the target action: the hinge is closed by the infant grasping the hinge or using an open palm to push the hinge into a closed position.

   1: The infant unsuccessfully attempts the target action: attempts to close the hinge without success (e.g. pushing at the hinge without fully closing it).

   0: The infant makes no attempt at the target action, or, the infant interacts with the hinge but not in any attempt to close it (e.g. bashing on hinge, mouthing hinge).

2. **Collapse cup**

   2: The infant intentionally and successfully performs the target action: collapses the cup by applying pressure to the top.

   1: The infant unsuccessfully attempts the target action: attempts to collapse the cup (e.g. by pressing against the top of the cup, but without sufficient force to collapse the cup).

   0: The infant makes no attempt at the target action, or accidentally collapses the cup (e.g. by mouthing the edge of the cup and causing it to collapse).

3. **Toy in cup**

2: The infant intentionally and successfully performs the target action: puts the toy inside the cup, either by releasing the toy into the cup or by holding the toy inside the cup.

1: The infant unsuccessfully attempts the target action: attempts to put the toy in the cup, or intentionally presses the toy against the cup (side or rim) without putting the toy inside.

0: The infant makes no attempt at the target action, or interacts with the cup and/or toy separately.

4. **Remove pipe end**

2: The infant intentionally and successfully performs the target action: pulls the end of the pipe off using their hands, fully dislodging the end piece.

1: The infant unsuccessfully attempts the target action: attempts to remove the pipe end (e.g. pulls at the target end without removing it).

0: The infant makes no attempt at the target action, or interacts with the pipe with no attempt to interact with the target end (e.g. bashing the pipe, mouthing the pipe).

5. **Rotate pipe**

2: The infant intentionally and successfully performs the target action: rotates the pipe clearly more than 90˚ at least once. The starting position of the hand can be any orientation (e.g. palm facing upwards or downwards).

1: The infant unsuccessfully attempts the target action: attempts to rotate the pipe, but not through at least 90˚ (e.g. slightly wiggling the pipe in the same motion as the demonstration).

0: The infant makes no attempt at the target action, or interacts with the pipe with no attempt to move it in a rotating motion.

5A2. Attention Following

5A2.1 Gaze Following

2: The child looks to the target object. The look must be as a result of E's look.

- To ensure the look is as a result of E's action, the action only counts as a 2 if it happens directly after the initial eye contact. So, after the initial eye contact, if the infant looks away from E (e.g. up, or to the non-target side), and only then to the target object, the look to the target object does not receive a "2". If the infant keeps looking at E for an extended period, then eventually turns to the correct object, a "2" can be given.
- Each time E re-establishes eye contact, the scoring "resets," giving the infant another opportunity to look at the target object.

1: The infant looks to the side where target object is located, but not to the object itself.

- To ensure the look is as a result of E's action, the action only counts as a 1 if it happens directly after the initial eye contact. So, after the initial eye contact, if the infant looks away from E (e.g. up, or to the non-target side), and only then to the target side, the look to the target side does not receive a "1". If the infant keeps looking at E for an extended period, then eventually turns to the correct side, a "1" can be given.
- Each time E re-establishes eye contact, the scoring "resets" giving the infant another opportunity to look at the correct side.

0: The infant only looks at E, or looks to the opposite side to the target object.

5A2.2 Point Following

The scheme is identical to that of gaze following, except that for a score of "1" or "2", the infant's look must occur as a result of the point (i.e., the infant must look at E's pointing finger and then directly to the target object or side, respectively).

5A3. Means-Ends Understanding

2: The infant intentionally and successfully obtains the toy using the cloth.

- The infant intentionally pulls on cloth until the toy arrives within their reach and they touch it.
- The infant visually attends to the toy at some point during this process.

1: The infant intentionally but unsuccessfully attempts to obtain toy using cloth.

- The infant intentionally pulls on the cloth in order to obtain the toy, but the toy does not end up within their reach.
- The infant intentionally pulls on the cloth in an attempt to obtain the toy, but the toy falls off table.

0: The infant makes no attempt to use the cloth to obtain the toy, or only accidentally obtains the toy. E.g.:

- The infant grabs the cloth to chew on it, and in doing so the toy moves within their grasp and they obtain it.
- The infant does not interact with the cloth at all.

- The infant only interacts with the cloth.
- The infant only reaches for toy.
- The infant communicates about the toy but makes no attempt to obtain it using the cloth.

5A4. Object Permanence Understanding

2: The infant successfully obtains the target object by removing the cloth and touches the target object.

- A “2” cannot be scored if the infant obtains the target object accidentally (e.g. by grabbing the cloth to chew on it, noticing the target object, and taking the target object).
- The infant does not need to pick up the target object, only touch it.

1: The infant intentionally but unsuccessfully attempts to obtain the target object. E.g.:

- The infant interacts with the cloth but does not manage to lift it off the target object.
- The infant begins to search for the target object, but loses interest.
- The infant manipulates the target object through the top of the cloth without obtaining it.

0: The infant makes no attempt to search for the target object, or only accidentally obtains the target object. E.g.:

- The infant obtains the target object accidentally (e.g. by grabbing the cloth to chew on it, noticing the target object, and taking the target object).
- The infant does not pull on the cloth at all.
- The infant only interacts with the cloth.

5A5. Independent Sitting

This coding scheme drew upon the definition provided by Rachwani and colleagues (2017).

2: The infant is able to sit independently for an extended period

- The infant sits with his/her bottom resting on a flat surface without external support (mother/cushion/Bumbo) and without support by the infant's hand(s) for at least 10 seconds.

1: Limited independent sitting:

- The infant sits with his/her bottom resting on a flat surface without external support or support of (a) hand(s), but for less than 10 seconds.
- Or, the infant sits with his/her bottom resting on a flat surface, but sitting in the "tripod" position (i.e. with one or both hands supporting their weight, with no external support). Here, if the infant's hand(s) is/are in contact with any surface, this is taken as supporting weight, unless it can be clearly established that this surface is not bearing any weight (e.g., the infant is manually investigating the surface).

0: No ability to sit, or sitting only with external support

- The infant does not sit at all, and is instead lying on his/her front or back.

- A sitting pose is maintained by the mother, and not by the infant him/herself. Here, any contact by the mother counts as providing support.
- The infant sits with the aid of some other kind of external support (cushion, Bumbo). Here, any contact with these sorts of supports counts as providing support, unless it can be clearly established that this surface is not bearing any weight (e.g., the infant is manually investigating the surface).

5A6. Self-Locomotion

This coding scheme drew upon the definition provided by Walle (2016)**.**

2: The infant is able to self-locomote forward a distance of at least twice his or her body length.

- Hands-and-knees crawling, commando crawling, scrambling, bum shuffling are all fine.
- It is a requirement that this movement is done without assistance (from the mother or by pushing off objects/surfaces).

1: The infant can self-locomote, but not forward towards desired location

- Non-forward crawling, or inconsistent forward motion (i.e., less than twice their body length) are accepted.

0: No self-locomotion whatsoever, or only rolling side to side.

Appendix 5B

Tables of Model Coefficients

See Appendix 3C for information regarding the interpretation of the tables, and Appendix 4B for information regarding the treatment of tasks in which there are session involving either no infants producing an instance of a behaviour for a given month, or 100% of participants producing an instance of a behaviour for a given month.

Table 5B1. Output of GLMM in section 5.1.1.2 modelling production of imitation (dyadic and triadic collapsed).

	Imitation Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.03	0.04	0.00 – 0.27	0.002**
Age (8 months)	6.97	8.11	0.71 – 68.23	0.095
Age (9 months)	28.35	32.92	2.91 – 276.03	0.004**
Age (10 months)	35.64	42.45	3.45 – 367.98	0.003**
Observations	97			
Marginal R^2 / Conditional R^2	0.348 / 0.447			

Note. ** $p < 0.01$.

Table 5B2. Output of GLMM in section 5.1.1.2 modelling production of triadic imitation.

	Triadic Imitation Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.21	0.13	0.06 – 0.71	0.012*
Age (9 months)	4.29	3.13	1.03 – 17.94	0.046*
Age (10 months)	5.52	4.27	1.21 – 25.14	0.027*
Observations	72			
Marginal R^2 / Conditional R^2	0.122 / 0.297			

Note. *$p < 0.05$.

Table 5B3. Output of GLMM in section 5.1.2.2 modelling production of attention following (gaze and point following collapsed).

	Attention Following Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.01	0.01	0.00 – 0.15	0.002**
Age (7 months)	6.31	9.74	0.31 – 129.95	0.233
Age (8 months)	10.76	16.55	0.53 – 219.20	0.122
Age (9 months)	34.40	54.07	1.58 – 748.88	0.024*
Age (10 months)	136.43	229.23	5.07 – 3673.79	0.003**
Observations	124			
Marginal R^2 / Conditional R^2	0.260 / 0.686			

Note. *$p < 0.05$, **$p < 0.01$

Table 5B4. Output of GLMM in section 5.1.2.2 modelling production of gaze following.

	Gaze Following Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.01	0.02	0.00 – 0.19	0.002**
Age (7 months)	2.46	3.41	0.16 – 37.47	0.518
Age (8 months)	2.46	3.41	0.16 – 37.47	0.518
Age (9 months)	6.87	9.03	0.52 – 90.25	0.143
Age (10 months)	37.73	51.65	2.58 – 551.99	0.008**
Observations	124			
Marginal R^2 / Conditional R^2	0.200 / 0.568			

Note. $^{**}p < 0.01$

Table 5B5. Output of GLMM in section 5.1.2.2 modelling production of point following.

	Point Following Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.01	0.02	0.00 – 0.21	0.003**
Age (8 months)	2.48	3.46	0.16 – 38.26	0.516
Age (9 months)	10.60	14.22	0.76 – 146.91	0.078
Age (10 months)	39.40	55.97	2.43 – 637.80	0.010*
Observations	99			
Marginal R^2 / Conditional R^2	0.227 / 0.620			

Note. $^{*}p < 0.05$, $^{**}p < 0.01$

Table 5B6. Output of GLMM in section 5.2.1.2 modelling demonstration of means-ends understanding.

	Means-Ends Understanding Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.23	0.14	0.07 – 0.75	0.015*
Age (8 months)	7.57	5.77	1.70 – 33.73	0.008**
Age (9 months)	12.56	10.27	2.53 – 62.35	0.002**
Age (10 months)	14.75	12.32	2.87 – 75.82	0.001**
Observations	97			
Marginal R^2 / Conditional R^2	0.200 / 0.443			

Note. $*p < 0.05$, $**p < 0.01$

Table 5B7. Output of GLMM in section 5.2.2.2 modelling demonstration of object permanence understanding.

	Object Permanence Understanding Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.23	0.14	0.07 – 0.75	0.015*
Age (8 months)	7.57	5.77	1.70 – 33.73	0.008**
Age (9 months)	12.56	10.27	2.53 – 62.35	0.002**
Age (10 months)	14.75	12.32	2.87 – 75.82	0.001**
Observations	97			
Marginal R^2 / Conditional R^2	0.200 / 0.443			

Note. $*p < 0.05$, $**p < 0.01$

Table 5B8. Output of GLMM in section 5.3.2.2 modelling self-locomotion.

	Self-Locomotion Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	-38.45	7.99	-54.11 – -22.80	<0.001***
Age (8 months)	12.24	5.01	2.43 – 22.06	0.014*
Age (9 months)	27.67	6.98	13.99 – 41.34	<0.001***
Age (10 months)	49.68	9.15	31.74 – 67.61	<0.001***
Observations	99			
Marginal R^2 / Conditional R^2	0.075 / 0.999			

Note. *$p < 0.05$, ***$p < 0.001$

Appendix 5C

Model Selection

Table 5C1. Corrected Akaike Information Criterion (AICc) scores for GLMs and GLMMs and their relative weighting.

Model Description	GLM AICc	GLM Weight	GLMM AICc	GLMM Weight
Imitation (Dyadic and Triadic) (Table 5B1)	138.1	0	109.1	1
Triadic Imitation (Table 5B2)	133.9	0	98.3	1
Attention Following (Table 5B3)	117.5	0.015	109.0	0.985
Gaze Following (Table 5B4)	115.9	0	95.4	1
Point Following (Table 5B5)	110.0	0	83.7	1
Means-Ends Understanding (Table 5B6)	144.7	0	124.5	1
Object Permanence Understanding (Table 5B7)	119.7	0.001	104.6	0.999
Self-Locomotion (Table 5B8)	79.2	0.002	66.5	0.998

Note. See Table 3D1 for details on interpreting the model selection table.

Appendix 7A

Interview Questions

The researcher asked only the non-bold questions below as the structured part of the interviews. When mothers provided written responses, they received the following set of directions and questions, and were asked to respond to those questions not in bold.

Let us know how your baby's behaviours are <u>different</u> or <u>new</u> compared to previous weeks!

- **What communicative changes have you noticed?**
    - Is your baby looking at you more than in previous weeks?
    - When does your baby look at you?
    - Does he/she ask you for things? How? (e.g. to be picked up, for food)
    - Does he/she make any gestures (waving bye-bye, pointing, any special shared gestures that you have?)
    - Have the noises that he/she makes changed? When does he/she make noises?
    - Does he/she copy you? When?
    - Does he/she have any games he/she likes to play with you? Are there any new games? (e.g. dropping toys on the floor, peekaboo etc.)
- **What physical changes have you noticed?**
    - How does your baby move him/herself around? (crawl, shuffle, standing with support, walking etc)
    - Can he/she sit by him/herself for a long time? How long?
    - Is he/she able to play with objects in new ways? (e.g. toys, food)
    - Is he/she able to control his/her hands and fingers in new ways?

- **What motivational changes have you noticed?**
    - How does your baby react to strangers?
    - How does he/she react to interesting things?
    - Does he/she show you interesting toys/objects?
    - How does he/she react to things that are surprising or scary?
    - Does he/she have any new favourite toys? What does he/she like about these new toys?
    - Do you read books together? What does your baby do as you read?

Appendix 7B

Full Interview Behavioural Coding Schemes

7B1. Independent Sitting

- **2:** The mother is certain the child can sit independently.
    - The threshold is 10 seconds of independent sitting. A "2" can be awarded if it can be established that the child can sit for at least 10 seconds (either because the length of time the child can sit is specified, or because the mother suggests the child can sit as long as he/she needs to.)
- **1:** The mother is certain that the child is capable of sitting independently for a limited time, or can only sit while supporting themselves.
    - Here, a limited time is less than 10 seconds. A "1" can be awarded if it can be established that the child can sit for under 10 seconds (either because the length of time the child can sit is specified, or because the mother suggests the child can sit, but not for an extended period.)
    - Cases of self-support include cases in which the child is holding onto some surface with their hand, or uses 1 or 2 hands to support themselves ("tripod" sitting).
- **0:** The mother is certain that the child does not sit independently or sit with support.
    - Sitting in a chair or supportive seat of some kind counts as a 0.

Note: After several weeks of confident sitting, there may be no reference to the child's sitting ability. In such cases, a 2 can be assigned. (a 2 must have been previously assigned to do this).

7B2. Self-Locomotion

- **2:** The mother is certain that the child is capable of self-locomoting consistently.
    - The threshold is being able to move themselves at least 2 full body lengths without help (caregiver assistance, pushing off objects).
    - If it is possible to establish the distance the child can move, use this as a guideline.
    - Otherwise, look for indications that the infant can "get themselves where they want to go", can crawl confidently, or other indications that the child is confidently and consistently self-locomoting.
    - Hands-and-knees crawling, commando crawling, scrambling, bum shuffling are all permitted.
- **1:** The mother is certain that the child has some ability to self-locomote, but not consistently.
    - This includes cases that the child can move him/herself forward some distance, but not at least 2 full body lengths. Use whatever indicators that are available to discern how the infant might be capable of forward motion.
    - A "1" is also assigned if the infant is only capable of backwards movement, regardless of distance.
    - A "1" is also assigned if the child locomotes by rotating between positions.
- **0:** The mother is certain that the child cannot self-locomote. Or, it is not sufficiently clear whether the child can self-locomote.
    - 0 is also assigned if the child's only movement is rolling.

Note: After several weeks of confident self-locomotion, there may be no direct reference to the child's self-locomotion abilities. In such cases, a "2" can be assigned (a "2" must have been previously assigned to do this).

7B3. Joint Attention Looks

- **2:** The mother is certain that the child intentionally produces looks that are being used to communicate about some specific target, either through being combined with a facial expression or with a communicative vocalisation.
    - The mother describes her child's behaviour in a manner that suggests she is fully confident that they are producing such looks, and does not express doubt.
        - "She looks at me to communicate."
        - "He looks to me to share what he is interested in."
        - "She shows me toys by looking at me."
        - "He'll tell me things by looking at me a certain way."
        - "She looks at me to try and get me to look at what she has."
    - For vocalisations:
        - Has to be clearly about something:
            - For example, "He cries to communicate he's sad" would not count as a "2".
        - Has to be clearly to the mother, not just any vocalisation (e.g. comments like "at me" or "for me")
            - For example:
                - "When she cries in a certain way, I know she's hungry"
                - vs.

        - "She'll look at her food and then shout towards me when she wants some more"
    - If the mother identifies a behaviour that does not fit what an experimenter would label as a joint attention look, they can still receive a "2" if the description is relevant and the mother is confident. For example, the mother may state:
        - "She looks at me with a blank expression but I know she's trying to tell me something"- she is confident that the infant is communicating, so it does not matter that the expression is blank.
        - "He looks to me to communicate after I chat to him" – it does not matter that the communicative act is in response to the mum, rather than being spontaneous.
- **1:** The mother believes the child may be producing joint attention looks (i.e., believes it is possible that the child is able to produce communicative looks, but expresses uncertainty).
    - A behaviour that is partial or not clearly communicative.
        - The mother describes the child looking to her in response to some object or event, but she is not clear if the child is trying to communicate.
    - A behaviour that the mum thinks might be communicative, but she cannot be sure.
        - Look for phrases that indicate hesitation or uncertainty, such as "sort of", "kind of", "somewhat" or "a bit".
        - Be aware of certain terms that may indicate uncertainty or may not, such as "like" (which can be a filler or a modifier).

        - E.g. “She, like, definitely communicates” versus “It’s like she communicates”
    - If there is doubt, code more conservatively (i.e., assign a “0” not a “1”).
- **0:** The mother is certain that the child is not engaging in any behaviour relevant to communicative looks.
    - The mother reports that the child will look to her, but not clearly in response to some stimulus.
    - Or, the mother states that her child does not spontaneously look to her.
    - Or, the child only looks to the mother to seek reassurance/when afraid.
        - “He looks at me for comfort if something scary happens.”
        - “He looks to check I’m still there.”
    - Or the mother interprets the child’s look as an invitation to join in what he/she is doing, rather than to communicate about some specific target.
        - E.g.: “She looks at me to get me to play with her.”

7B4. Showing Gestures

- **2:** The mother is certain that the child intentionally produces showing gestures.
    - The mother describes her child’s behaviour in a manner that suggests she is fully confident that they are capable of producing intentional, conventional showing gestures.
    - It does not matter if the mother subsequently describes behaviour that would not fit what an experimenter would label as a conventional showing gesture, as long it is clearly some sort of gesture. For example, the mother may describe:
        - “She shows me the toy by putting it on my lap”

        - **“**He holds the toy in the air and I’m sure he’s showing it to me”
    - If the mother affirms that the child shows her toys/objects, but then goes on to describe showing through non-gestural means (e.g. looking, vocalising) then a 0 is awarded. The mother must have confidence that the infant is showing *gesturally* for a “2” to be awarded.
- **1:** The mother reports that the child may be producing showing gestures (i.e., reports it is possible that the child is able to produce showing gestures, but expresses uncertainty). Or, the mother is certain that the child is producing gestures that are related to the production of showing gestures.
    - Look for phrases that indicate hesitation or uncertainty, such as “sort of”, “kind of”, “somewhat” or “a bit”,
    - Look for phrases that indicate that the behaviour is not clear or not conventional, such as “sort of showing”, “showing but not properly” or “she’s almost got it”.
    - If there is doubt, code more conservatively (i.e., assign a 0 not a 1).
- **0:** The mother is certain that the child is not engaging in any behaviour relevant to showing.
    - Or, the mother does not report any information regarding showing, or states that her child does not perform gestures in general.
    - See “2” section; if the mother describes non-gestural showing (looking, vocalising), then a “0” is awarded.

Appendix 7C

Tables of Model Coefficients

Table 7C1. Output of GLMM in section 7.2.1.1 modelling independent sitting, maternal versus researcher assessments, with an interaction between age and assessment type.

	Independent Sitting Score			
Predictors	Log-Odds	SE	CI	*p*
(Intercept)	-2.46	1.33	-5.08 – 0.15	0.065
Age (7 months)	5.88	2.37	1.23 – 10.54	0.013*
Assessment Type (Maternal)	3.03	1.47	0.15 – 5.91	0.040*
Age (7 months)*Assessment Type (Maternal)	-0.54	1.78	-4.04 – 2.95	0.761
Observations	100			
Marginal R^2 / Conditional R^2	0.380 / 0.874			

Notes. ***p < 0.001. Assessment Type was a binary categorical variable. The categories were "Researcher" (reference category) and "Maternal". To avoid an unbalanced model (due to all participants being capable of independent sitting as reported by both mothers and researchers at 9 and 10 months), only scores at 6, 7 and 8 months were included in the model. Because of large values for the estimates and standard errors (due to high numbers of infants engaging in independent sitting), values are presented on the log-odds scale.

Table 7C2. Output of GLMM in section 7.2.1.2 modelling self-locomotion, maternal versus researcher assessments, with an interaction between age and assessment type.

	Self-Locomotion Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	-28.67	6.62	-41.63 – -15.70	<0.001***
Age (9 months)	19.60	5.27	9.27 – 29.93	<0.001***
Age (10 months)	48.81	10.25	28.71 – 68.91	<0.001***
Assessment Type (Maternal)	10.46	3.71	3.19 – 17.74	0.005**
Age (9 months) * Assessment Type (Maternal)	7.90	4.45	-0.83 – 16.62	0.076
Age (10 months) * Assessment Type (Maternal)	-2.04	5.49	-12.81 – 8.73	0.710
Observations	149			
Marginal R^2 / Conditional R^2	0.233 / 0.998			

Notes. $^{**}p < 0.01$, $^{***}p < 0.001$. Assessment Type was a binary categorical variable. The categories were "Researcher" (reference category) and "Maternal". Because there was only one participant who received different assessments at 6 months, and because scores were identical at 7 months, the fitted model only examined scores at 8, 9 and 10 months to avoid an imbalanced model.

Table 7C3. Output of GLMM in section 7.2.2 modelling production of joint attention looks, maternal versus researcher assessments, with an interaction between age and assessment type.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.76	0.36	0.30 – 1.91	0.562
Age (7 months)	1.46	0.90	0.44 – 4.87	0.540
Age (8 months)	6.51	4.51	1.67 – 25.30	0.007**
Age (9 months)	5.02	3.35	1.35 – 18.60	0.016*
Age (10 months)	18.38	16.23	3.25 – 103.80	0.001**
Assessment Type (Maternal)	0.04	0.04	0.00 – 0.37	0.005**
Age (7 months) * Assessment Type (Maternal)	3.52	4.74	0.25 – 49.32	0.350
Age (8 months) * Assessment Type (Maternal)	2.73	3.63	0.20 – 37.11	0.452
Age (9 months) * Assessment Type (Maternal)	5.22	6.88	0.39 – 69.18	0.210
Age (10 months) * Assessment Type (Maternal)	5.07	7.36	0.29 – 87.38	0.264
Observations	248			
Marginal R^2 / Conditional R^2	0.417 / 0.528			

Notes. *$p < 0.05$, **$p < 0.01$. Assessment Type was a binary categorical variable. The categories were “Researcher” (reference category) and “Maternal”.

Table 7C4. Output of GLMM in section 7.2.2 modelling production of joint attention looks, maternal versus researcher free play assessments, with an interaction between age and assessment type.

	Joint Attention Look Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.07	0.05	0.02 – 0.32	0.001**
Age (7 months)	1.00	1.05	0.13 – 7.93	0.997
Age (8 months)	3.97	3.55	0.69 – 22.95	0.124
Age (9 months)	11.03	9.60	2.00 – 60.71	0.006**
Age (10 months)	11.67	10.19	2.11 – 64.61	0.005**
Assessment Type (Maternal)	0.47	0.59	0.04 – 5.64	0.550
Age (7 months) * Assessment Type (Maternal)	4.91	7.75	0.22 – 108.31	0.314
Age (8 months) * Assessment Type (Maternal)	4.08	5.84	0.25 – 67.41	0.326
Age (9 months) * Assessment Type (Maternal)	2.14	3.01	0.14 – 33.73	0.589
Age (10 months) * Assessment Type (Maternal)	7.00	9.99	0.43 – 114.76	0.172
Observations	248			
Marginal R^2 / Conditional R^2	0.311 / 0.413			

Notes. ***p* < 0.01. Assessment Type was a binary categorical variable. The categories were “Researcher” (reference category) and “Maternal”.

Table 7C5. Output of GLMM in section 7.2.3 modelling showing gestures, maternal versus researcher assessments, with an interaction between age and assessment type.

	Showing Gestures Score			
Predictors	Odds Ratios	SE	CI	*p*
(Intercept)	0.02	0.02	0.00 – 0.18	0.001**
Age (9 months)	7.96	9.60	0.75 – 84.48	0.085
Age (10 months)	53.95	66.08	4.89 – 595.02	0.001**
Assessment Type (Maternal)	3.76	4.71	0.32 – 43.67	0.289
Age (9 months) * Assessment Type (Maternal)	0.48	0.70	0.03 – 8.45	0.614
Age (10 months) * Assessment Type (Maternal)	0.30	0.43	0.02 – 4.93	0.399
Observations	149			
Marginal R^2 / Conditional R^2	0.277 / 0.565			

Notes. $^{**}p < 0.01$. Assessment Type was a binary categorical variable. The categories were "Researcher" (reference category) and "Maternal". Because there were no reports at 6 months, and because there was only one participant who received a score at 7 months, the fitted model only examined scores at 8, 9 and 10 months to avoid an imbalanced model.

Appendix 7D

Model Selection

Table 7D1. Corrected Akaike Information Criterion (AICc) scores for GLMs and GLMMs and their relative weighting.

Model Description	GLM AICc	GLM Weight	GLMM AICc	GLMM Weight
Independent Sitting, Maternal versus Researcher (Table 7C1)	114.1	0	95.1	1
Self-Locomotion, Maternal versus Researcher (Table 7C2)	122.7	0.007	112.7	0.993
Joint Attention Looks, Maternal versus Researcher (Table 7C3)	303.7	0	276.9	1
Joint Attention Looks, Maternal versus Researcher Free Play (Table 7C4)	295.3	0	267.1	1
Showing Gestures, Maternal versus Researcher (Table 7C5)	175.3	0	153.6	1

Note. See Table 3D1 for details on interpreting the model selection table.