Are you *like me*? Maybe, but I will not imitate you!

A longitudinal study on newborns and infants' imitation and conspecific identification skills

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Psychology

University of Alberta

Abstract

Imitation abilities in infancy have long been proposed to be the building blocks of later social cognition skills (e.g., Gopnik & Meltzoff, 1994). Although Piaget (1953, 1962) argued that it was only in the coordination of secondary schemes that infants showed signs of true imitation, his approach was challenged by Meltzoff and Moore (1977), who argued that humans were capable of matching adults' facial gestures from birth. Meltzoff and Moore (1977, 1983, 1989, 1994) proposed a new theory that explained their revolutionary discovery: the *like me* framework. The core of the *like me* framework is that infants are born with imitative skills, which allows them to match people's behaviours and to recognize that the adult modelling a certain behaviour is just like them. In the current study, I aimed to replicate Meltzoff and Moore's findings, as well as to test the *like me* equivalence framework by investigating if newborns are biased to specifically imitate humans (i.e., their conspecifics), or more broadly, face-like stimuli (e.g., an ape). Infants were longitudinally assessed (up to 7 days after birth, and at 1, 2, and 3 months of age). In each assessment, they were prompted with a moving pen, an ape robot protruding its tongue to the side, and an adult modelling lateral tongue protrusion. Infants' tongue movements were coded according to their direction (forward or lateral tongue protrusion). Surprisingly, I did not find any sign of imitation across conditions and time points. I argue that I did not replicate Meltzoff and Moore's findings because human beings are not capable of imitation either at birth or in the first the 3 months of age. I suggest that the associative sequence model (Ray & Heyes, 2011) or Jones' (2015, 2016) revision of Piaget's (1953, 1962) theory might be a way to predict the emergence of imitation in infancy.

Key words: imitation; conspecific; infancy; like-me hypothesis

Preface

This dissertation is an original work by Poliana Gonçalves Barbosa. The research project, of which this dissertation is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Do newborns imitate only other humans? An investigation of newborns' conspecific identification abilities", No. Pro00053843, FEBRUARY 9, 2015

Dedication

To Aragorn, Daenerys, Elijah, Hermione, Lorelai, Morgana, Muad'Dib, Newt, Pollyanna, Rey, Sherlock, and Sophie for inspiring me to pursue my dreams, to be strong and fearless, and to believe in myself.

To Victor Frankl, who never ceased to inspire me with his story of life.

To my piano; my embarrassment, yet my best comfort.

Everything can be taken from a man but one thing: the last of human freedoms – to choose one's attitude in any given set of circumstances, to choose one's own way.

– Viktor Frankl, *Man's Searching for Meaning,* 1946

Acknowledgments

Dear Marlos, how can I thank you enough? You are my love, my friend, my family, my support, my life. Thank you for all the proofreading and enthusiasm, for driving me around Edmonton and waiting in our cold car so I could collect my data; thank you for the coffee in the morning and for the hugs in the evenings!

Elena, I could never dream of having someone so intelligent and kind like you to guide my steps. Every time I slipped, you offered me traction; every time I had too much traction, you shook my support; always in the right amount to motivate and challenge me. Because of you, I grew as a person and as a scientist. I learned to love and enjoy what I do. Thank you for all the fun we had!

Sandra and Cor, you inspired me so much! I knew I could always count on you whenever I felt lost in my data and in my ideas. Thank you for being my light at the end of the tunnel.

Wendy, you helped me find my “research” voice. Chris, you gladly jumped into a moving canoe and helped me to keep its balance. Jeff, you brought humanity to the craziness of grad school. I am lucky to have had so many wonderful people around me! Thank you.

Naheed, Lisa, and Dayuma, you were like older sisters to me, who I would always go to when I needed advice for my life (all the Bronfenbrennian aspects of it!). Axel, Erin, Freya, Gabriela, Jamin, Jenna, Jiawen, Katy, Mike, Neil, Nigel, Robyn, Saira, and Teresa; you are my UofA family. Thank you for listening to me and for taking care of me.

Aleesha, Amina, Brandi, Harkirat, Nicole, Rachel, Reshani, Ruta, Sasha, and Winney, what would be of me without you? You are *my precious*… Thank you very much!

Glad lab, we shared so many colours and emotions in our meetings! Every time I wanted to talk about the marvellous world of infancy and language development, you endured and even smiled. I want to thank you for that.

Al, Anita, Ash, Kerry, Lill, and Nicole, I am thankful to all of you; every time I cried for help, you giggled with the perfect solution. Isaac and Lou, thank you for the scariest ape robot known to us, i.e., Chimsky (yes, it got a name!).

To everyone cheering for me in Brazil, thank you for all the warmth and hours of Skype that made me bravely face the winter in Canada. Mom, dad, I am almost there!

Minsky and Marie, you are the soundtrack of my existence, my cuddling companies. Thank you for all the distraction and for bringing out the best in me!

Finally, to all the families that opened their house to me and my research, to all the babies that smiled, cried and slept during my data collection, I will be forever thankful to you!

It all made sense for everything I did was *in love*; everyone I met, was *through love*!

Table of Contents

List of Tables

List of Figures

Introduction

The importance of imitation to human development is indisputable. Imitation abilities in infancy have long been considered to be the building blocks of later social cognition skills, such as language acquisition, self-other understanding, and theory of mind (Tomasello, 1999; Meltzoff & Gopnik, 1993; Rochat, 2003; cf. Suddendorf, Oostenbroek, Nielsen, & Nielsen, 2013), as well as the basis for scaffolding socio-emotional development, such as the development of attachment (Meltzoff, 1990; Nagy and Molnar, 2004).

As one example, Tomasello (1999, 2003) has given great importance to imitation in his theory of language acquisition. According to him, when infants start to acquire language, they are actually imitating intentional acts they have seen other adults do. For instance, a parent can point to a dog and say "dog" in order to grab the infant's attention and direct it to the animal. Later on, we see the same infant pointing and saying "dog" also as an attempt to grab the parent's attention and manipulate it, i.e., to direct the parent's attention to the animal. Infants thus do not initially learn the categorical and abstract meaning of the word "dog," but rather they learn the communicative intent behind it and imitate that intent. In the example given, infants learn that they can direct other people's attention to a specific animal by saying "dog." This kind of imitative act is called role-reversed imitation and is a key concept in Tomasello's theory. In more practical terms, the connection between imitation and language can be illustrated by children with autism, who generally have great difficulties not only in imitating people's actions but also in developing language skills (see Frith, 2008, for a review).

Besides language, early imitative skills are also claimed to support the development of self-other understanding (Rochat, 2003; see also Jackson, Meltzoff, & Decety, 2005). Rochat's theory of self-awareness development encompasses five qualitative and successive stages:

differentiation (e.g., implicit-sensorimotor knowledge that “I am different from you”), situation (e.g., implicit-sensorimotor knowledge that “I can move and orient towards objects”), identification (e.g., explicit-cognitive knowledge that “that is me in the mirror”), permanence (e.g., explicit-cognitive knowledge that “I and that picture of a younger me are the same”) and self-consciousness (explicit-cognitive knowledge that “people are also aware of who I am”). According to Rochat, when infants imitate adults’ movements, they are showing at least an implicit sense of self, meaning that infants can differentiate themselves from others and also orient their movements accordingly to others’ movements (cf., Welsh, 2006). Without differentiating from others and identifying the similarities with others in order to match their behaviours, infants do not move towards more elaborated knowledge of their selves, e.g., self-identification as measured by the mirror test (Gallup, 1970).

Pushing further the importance of imitation in infancy, Meltzoff and Gopnik (1993; Gopnik & Meltzoff, 1994, Meltzoff, 1999) state that imitation in infancy is the underpinning of theory of mind. Theory of mind can be defined as the understanding that human beings possess mental states (e.g., beliefs, desires, intentions, etc.) that can differ from each other (Wimmer & Perner, 1983). The authors propose that through imitation infants can form primitive maps between perception and production, i.e., their internal states and their actions. While involved in imitative games, infants are connecting a visible world of others to their internal mental states; infants can then map their mental states and sensations onto others’ bodies, and vice-versa. For instance, if an infant imitates a sad expression from her/his caregivers, it (the imitation of sad expression) can generate certain sensations in the infant’s own body. Such proprioceptive sensations can clue in the infant on what that other person might be feeling. Inferences can then be drawn, and the first steps towards the development of theory of mind are taken, i.e., the recognition that we all have mental states. Support for the authors' proposal comes from children with autism who are known to struggle in several imitative and theory of mind tasks (see Frith, 2008, for a review). Gopnik and Meltzoff speculate that such theory of mind deficit might be due to earlier difficulties with imitation. In fact, the authors propose that earlier autism diagnoses would be possible if professionals investigated infants' developmental delays in imitation (see also Marshall, & Meltzoff, 2015).

Beyond social cognition, and perhaps more obviously, imitative interactions in infancy have also been linked to attachment development in infancy (Meltzoff, 1999; Nagy & Molnar, 2004). Attachment is the emotional bond between infant and caregiver; it is the infant's belief that s/he can explore around and engage with other people, as long as s/he can return to her/his caregiver (Ainsworth, Blehar, Waters, & Wall, 1987; Bowlby, 1969). One of the possible ways that infant and caregiver start to develop this emotional tie is through early imitative games. Imitation can be seen as a first way that caregiver and infant communicate "sense" with each other, i.e., behave in synchronous manner, offering a contingency to each other's actions. For instance, Meltzoff (1990) has shown that infants like adults who match their behaviours better than adults who do not. Infants smiled and laughed more when being imitated than when the parents were not imitating them. At the same time, parents find it enjoyable when their infants match their behaviours (Lewis, 1979). This scenario can contribute to the strength of the emotional connection between caregiver and infant. In addition, Nagy and Molnar (2004) have shown that imitation and provocation of imitation by infants is accompanied by heart rate acceleration and deceleration, respectively. They argue that these heart-rate changes are a sign of social orientation and expectation, a communicative exchange between infant and adult. Nagy and Molnar speculate that imitative games, early in infancy, can actually be a form of imprinting in human beings (i.e., an innate drive that allows for the fast learning of characteristics of a stimulus – within a critical period –, providing a sense of identification; Lorenz, 1991).

Finally, Shea (2009) has advanced a broader claim about the importance of imitation. The author theorizes that imitative skills are an evolutionary trait acquired by *Homo sapiens.* Beyond being foundational to later emotional, and social cognitive skills, imitation abilities are the reason why our cultures are more complex than the culture of other species that are also capable of social learning (e.g., apes). According to Shea, infants tend to imitate other people unselectively and blindly (c.f., Buttelmann, Zmyj, Daum, Carpenter, 2013), which is unique to humans. This tendency brings a pronounced evolutionary advantage to our species as imitation makes possible the transmission of behavioural phenotypes and culture advances throughout generations. Therefore, human discoveries are not lost with past generations (see also Tomasello, 1999). Shea argues in favour of an imitation-based inheritance system, implying that human beings are born with the ability to imitate.

All the theories discussed highlight the importance of imitation to the development of humans. Furthermore, they led me to ask (like Shea, 2009, did) if and how infants acquire imitation skills. One of the objectives of the present study is to experimentally test the hypothesis that infants are born with the ability to imitate and/or if such ability develops throughout the first three months of life. Following Meltzoff and Gopnik's (1993; Gopnik & Meltzoff, 1994, Meltzoff, 1999, 2005, 2007) reasoning, the answer to this inquiry could help with the early identification techniques for infant disorders and the elaboration of intervention programs early in development.

When does Imitation Begin?

Given the importance of imitation in humans' social behaviour, it is perhaps unsurprising that most researchers suggest that it emerges within the first year of life (e.g., Meltzoff & Moore, 1977; Nagy & Molnar, 2004; Piaget, 1962). However, there is some disagreement as to when in the first year "true" imitation emerges. According to Piaget (1953, 1962), the first imitative events in an infant's life encompass behaviours that the infant does spontaneously and repeats in circular reactions (i.e., acquired functional associations/movements that culminate in a sensorial effect), as well as behaviours that produce sounds or any observable outcome. In the beginning of the sensorimotor stage, the infant discovers interesting behaviours by chance and reproduces them in order to obtain certain pleasing effects. As an example, let us imagine the following scenario: an infant laughs while saying "mama;" the mother notices the infant's behaviour and, looking at the infant, she mimics the infant's behaviour, i.e., she laughs and say "mama." The infant finds the mother's facial expression and the sound that she produces interesting, thus, in order to keep the mother doing that, the infant keeps smiling and babbling. In this scenario, despite the matching between infant's and mother's behaviours, Piaget does not consider it to be true imitation as the infant did not intentionally match the mother's behaviour. According to the author, the infant is only trying to elicit a certain reaction from the mother. Nonetheless, this kind of "matching game" is important as it produces a juxtaposition of infant's proprioceptive sensations and the visual information provided by the mother, a first step towards the acquisition of imitation skills. According to Piaget, it is not before the coordination of secondary schemes (~ 8 to 12 months of age) that infants show signs of true imitation, first of novel movements that produce visual feedback, and later of unseen movements, such as facial expressions.

The Piagetian approach was challenged by Meltzoff and Moore (1977, c.f. Anisfeld, 2005), who argued that neonates were capable of matching adults' facial gestures, being capable of imitation earlier than Piaget (1953, 1962) thought. In a series of experiments (see Table 1), the authors presented infants, ranging from 42 minutes of age to 3 months of age, to an adult displaying one of the following behaviours: tongue protrusion, mouth opening, lip protrusion, and finger extension. In these experiments, an adult positioned in front of the newborns/infants and modelled a facial or a digital gesture for a few seconds (varying from 15 seconds to 40 seconds depending on the study), then stopped the gesture and kept a passive face for a few seconds (also varying from 15s to 40s). This series was generally repeated 3 to 5 times. While the experimenter was modelling the gestures, the newborns usually had a pacifier in their mouths to avoid the infants' imitation of extraneous experimenter gestures. After coding for infants' behaviours (e.g., infants' frequency of tongue protrusion and mouth opening), between-condition analyses were run (e.g., tongue protrusion condition vs. mouth opening condition). Meltzoff and Moore found that the newborns and infants produced more tongue protrusion when seeing the tongue protrusion displayed by the adult (tongue protrusion condition), than when seeing the mouth opening displayed (mouth opening condition). The same was true of the mouth opening behaviour, which was produced more frequently when infants were seeing the adult opening the mouth than protruding the tongue. With such consistent results involving newborns, the authors concluded that humans are born with the ability to imitate. It is important to highlight, though, that when within condition analyses were run (e.g., frequency of tongue protrusion vs. frequency of mouth opening within the same condition), the authors usually found that, overall, there was a higher frequency of tongue protrusion than mouth opening in all the conditions, i.e., there was a higher frequency of tongue protrusion than mouth opening on both tongue protrusion and mouth opening modelling conditions.

Following Meltzoff and Moore's seminal study, several other researchers started to investigate the existence of neonatal imitation. Table 1 summarizes studies run by several researchers who replicated the finding that newborns imitate facial gestures, facial expressions, and finger movements, within hours/days after birth (exceptions are Jacobson, 1979, Jones, 1996, and Oostenbroek et al., 2016, which are discussed later).

Table 1

Summary of Studies Seeking Evidence of Neonatal Imitation

Study Reference	*N*	Age	Stimuli	Results
Meltzoff & Moore, 1977	6; 12	12-21 days	TP; MO; FG	Positive[1]
Jacobson, 1979	24	6, 10,14 weeks	TP; HO; OB	Negative[2]
Field et al., 1982	74	36 hours	FX;	Positive
Meltzoff & Moore, 1983	40	42 min -71 hours	TP; MO	Positive
Abravanel & Sigafoos, 1984	90	4-21 weeks	TP; MO; HO; CT; EB	Positive for TP
Field et al., 1984	96	35-42 hours	FX	Positive

Note: [1]Positive= evidence in favour of imitation; [2]Negative= no evidence in favour of imitation; CT= chin tapping; CS= cheek swelling; EB= eye blinking; FE= finger gestures; FX= facial expressions; HM= head movement; HO= hand opening; LP= lip protrusion; MC= mouth clutching; MO= mouth opening; OB= objects; TP= tongue protrusion; VG= vocal gestures.

Table 1 Continue

Study Reference	*N*	Age	Stimuli	Results
Fointance, 1984	83	1-6 months	TP; MO; HO; FG; EB; CS	Positive for some
Heimman & Schaller, 1985	13	14-21 days	TP; MO	Positive
Vinter, 1986	36	2-5 days	TP; HO	Positive
Kaitz et al., 1988	26	10-51 hours	FX, TP	Positive for TP
Reissland, 1988	12	1st hour	MO; LP	Positive
Heimann et al., 1989	32	2 days-3 months	TP; MO; LP	Positive for TP
Meltzoff & Moore, 1989	40	< 72 hours	TP; HM	Positive
Legerstee, 1991	27	5-8 weeks	TP; MO; OB	Positive
Meltzoff & Moore, 1992	32; 16	6, 11 weeks	TP; MO	Positive
Meltzoff & Moore, 1994	40	6 weeks	TPside; MO	Positive

Note: [1]Positive= evidence in favour of imitation; [2]Negative= no evidence in favour of imitation; CT= chin tapping; CS= cheek swelling; EB= eye blinking; FE= finger gestures; FX= facial expressions; HM= head movement; HO= hand opening; LP= lip protrusion; MC= mouth clutching; MO= mouth opening; OB= objects; TP= tongue protrusion; VG= vocal gestures.

Table 1 Continue

Study Reference	*N*	Age	Stimuli	Results
Jones, 1996	28; 20; 2	3-30 weeks	TP; MO	Negative
Lundy et al., 1996	40	24-72 hours	FX	Positive
Anisfeld et al., 2001	83	40 hours	TP; MO	Positive for TP
Chen et al., 2004	25	1-7 days	/a/ (MO); /m/ (MC)	Positive
Nagy & Molnar, 2004	45	3-54 hours	TP	Positive
Nagy et al., 2007	43	3-96 hours	FG	Positive
Nagy et al., 2013	121	5 days	TP	Positive
Coulon et al., 2013	36	16-82 hours	/a/ (MO); /i/ (MC)	Positive
Nagy et al., 2014	121	2 days	FG	Positive
Oostenbroek et al., 2016	106	1, 3, 6, 9 weeks	TP, MO, FX, FP; VG; OB	Negative

Note: [1]Positive= evidence in favour of imitation; [2]Negative= no evidence in favour of imitation; CT= chin tapping; CS= cheek swelling; EB= eye blinking; FE= finger gestures; FX= facial expressions; HM= head movement; HO= hand opening; LP= lip protrusion; MC= mouth clutching; MO= mouth opening; OB= objects; TP= tongue protrusion; VG= vocal gestures.

Meltzoff and Moore (1992, 1994) also replicated and expanded their first findings by showing that 6-week old infants increased their frequency of tongue protrusion independently of whether the adult modelling the behaviour was familiar or unfamiliar (i.e., their mother or the experimenter), or if the behaviour was presented in a still or dynamic way. The authors also showed that 6-week-olds produced mouth-opening movements after a 24-hour delay when brought into the presence of the experimenter who had previously modelled the behaviour for the infant.

More impressively, 6-week-olds were observed by Meltzoff and Moore (1994) to imitate behaviours considered rare in their (infants') behavioural repertoire. Infants were shown to modify their tongue protrusion when presented with an adult doing a tongue protrusion to the side of the mouth midline. Over the experimental trials, the authors recorded the infants performing the following sequence of movements: 1st small non-midline tongue protrusion, 2nd small tongue protrusion to the side, 3rd large tongue protrusion, and 4th large tongue protrusion to side. In the current study, I tried to replicate and expand Meltzoff and Moore's results with newborns, 1, 2, and 3 month-old infants.

Given that the infants in Meltzoff and Moore (1992, 1994) studies were actively modifying their own behaviour to match that of the adult, the authors concluded that human neonates were clearly imitating the adult's behaviour, not simply emulating an interesting effect as previously proposed by Piaget (1962). In the midst of such revolutionary discovery and several replications of their results, Meltzoff and Moore (1997, 2002; Meltzoff, 2005, 2007) took a next step and proposed a new theory explaining their findings: the *like me* framework.

The *like me* framework. The core of the *like me* framework is that infants are born with imitative skills, which allows them to match peoples' behaviours and to recognize that the adult modelling a certain behaviour is just like them. The *like me* framework encompasses three main assumptions.

The first assumption is the action-perception supramodal representation system (Meltzoff, 2005, 2007). According to Meltzoff, humans have an active intermodal mapping system that is functional from birth. Such a representational system is required to explain the fact that infants perform an intermodal matching between their body (proprioception), and the other person's body (action). For instance, in Meltzoff and Moore's experiments, newborns matched their tongue to another person's tongue, as if matching a target, even though they could not see their own behaviour. Nonetheless, in spite of the evidence of newborn imitation, this representational system proposed by the authors needs to be regarded as something very broad and rudimentary, as in the lateral tongue protrusion matching experiment infants generally matched the absolute direction of the model, similar to mirror reflection (contralateral imitation was very infrequent; Meltzoff, & Moore, 1994). In fact, there is evidence that cross-modal somatosensory mapping develops very slowly throughout infancy, with remapping happening in response to new experiences (Rigato, Ali, Van Velzen, & Bremner, 2014)

A second assumption of the *like me* framework is the first-person experience (Meltzoff, 2005, 2007). Meltzoff proposes that while imitating, infants are connecting their own mental experiences with their own behaviours, i.e., linking invisible internal states to external behaviours.

The third assumption is the understanding of other people. Meltzoff argues that through imitation infants can actively identify people and communicate with them. The idea is similar to how Piaget (1953) described infants discovering the world by acting on it. Through imitation infants can "act on" people, coming to know them, i.e., to identify and to recognize familiar people from unfamiliar people. After the imitation experiments, if infants were brought back to the room and saw the experimenter, they started to produce the behaviour they had previously learned (e.g., infants started to open their mouths as if indicating that they knew/remembered the experimenter; Meltzoff and Moore, 1992). Besides, infants can ascribe to the other their first-person experience. Finally, infants ascribe the mental states that generally go with their behaviours to the adult performing those same behaviours.

In sum, the *like me* framework can be explained as follows (not necessarily in this order):

- when an infant imitates an adult, the infant is “acting on” the adult to recognize and to come to know the adult;
- while the infant imitates the adult’s behaviour, the infant is matching the adult’s actions to his/her own;
- also, while imitating and matching behaviours, the infant comprehends his/her behaviour as commensurate with the adult’s behaviour;
- all these processes lead to the identification with the adult through the realization that “that person is *like me*;” this realization supports inferences regarding the adult’s behaviour by the infant (e.g., “that person likes cookies just *like me*”).

Therefore, contrary to some theories (see Tomasello, 1999; Vygotsky, 1978), Meltzoff (2005, 2007) is arguing that infants imitate to recognize, to comprehend and to identify with other people (*like me* equivalence), which essentially implies that infants come to know the other and themselves through a first-person perspective, and not through the other. In a sense, imitation would be a sensorimotor way of sharing internal states in early infancy (Meltzoff, & Gopnik, 1993).

Mirror neurons and the *like me* framework. More recently, Meltzoff and colleagues have explained neonatal imitation and the self-other equivalences in terms of mirror neuron activation (Marshall, & Meltzoff, 2014, Marshall, Saby, & Meltzoff, 2013; Saby, Marshall, & Meltzoff, 2012; see also Simpson, Murray, Paukner, & Ferrarin, 2014; Yoo, Cannon, Thorpe, & Fox, 2016). First discovered in macaques, mirror neurons were shown to fire whenever a macaque performed or observed another doing a similar action (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). After this discovery, several researchers have spotted mirror neuron *mu*-waves in humans, concluding that humans also have mirror neurons, and theorizing that these neurons are essential to action understanding (see Molenberghs, Cunnington, & Mattingley, 2012, and Caspers, Zilles, Laird, & Eickhoff, 2010, for a summary of these studies). Although there is no empirical evidence supporting this relation between mirror neurons and action understanding (see Richard, Bird, Catmur, Press, & Heyes, 2014 for further discussion), some authors have suggested that dysfunctions in mirror neurons might explain the absence of neonatal imitation in some newborns, and even the development of autistic disorders (Marshall, & Meltzoff, 2014, 2015; Saby et al., 2012; Simpson et al., 2014).

According to Meltzoff and Marshall (2014), studies showing the existence of mirror neuron *mu*-waves in infants (e.g., Marshall, Bar-Haim, Fox, 2002) can be understood as further evidence for the *like me* framework. Basically, Meltzoff's action-perception supramodal representation system is translated into mirror neurons, as both are said to provide infants with the equivalences (i.e., mapping) between their own actions and other people's actions (Boyer, & Berthental, 2016; Marshall, & Meltzoff, 2014; Simpson et al., 2014; c.f., Richard et al., 2014). Indeed, Ferrari, Gallese, Rizzolatti, and Fogassi (2003) have shown that monkeys' mirror neurons fire in the presence of intransitive movements such as tongue and lip protrusion (and not only goal-directed behaviours and/or hand movements as previously thought).

While the existence of mirror neurons seems to explain neonatal imitation and how infants are capable of forming self-other correspondence (*like me* framework) from birth, there is a lack of consensus in the literature regarding the functions of mirror neurons in humans. The problem is due to the fact that researchers observed mirror neuron *mu*-waves in different brain regions in humans and in macaques (Richard et al., 2014). More importantly, there is also no agreement in the literature regarding the developmental origin of mirror neurons in humans. In sum, there is not enough evidence to claim any causality, i.e., whether mirror neurons are a prerequisite for imitation, or, conversely, if imitative experiences and associative learning skills trigger their development (see Cuevas, & Paulus, 2016; and Richard et al., 2014, for further discussion).

Is imitation of other people the best way to test the *like me* framework? Considering that the function of mirror neurons in humans is still unclear, experimental studies in infants' imitation skills seem to be a way of testing whether the *like me* framework is thorough. As mentioned before, the core feature of the framework proposed by Meltzoff is that even a 42-minute old newborn can imitate other people, thus understanding that other people are *like him/her*. However, is it the ability to imitate other people the most adequate test of the *like me* premise? Do neonatal imitative behaviours indicate that newborns know they are similar to other human beings? Further evidence for the *like me* equivalence mapping would be revealed if newborns can not only imitate, but also prefer to imitate humans over other beings, like apes. This would imply that the infant perceives other humans' behaviours as commensurate with his/her own, but do not recognize such commensurability with apes' behaviours, for instance.

Such questioning is vital given that it is well known in the literature that newborns have a strong preference for face-like stimuli (see Table 2 below for a summary of these studies). Thus, it could be that Meltzoff and Moore's (1977-1994) newborns were not actually identifying with other people and recognizing them as similar, but simply responding to the movement of face-like stimuli they saw, very much like an imprinting behaviour. The testing of this hypothesis is the primary research objective of the current dissertation. Here I compare infants' reaction to an experimenter and an ape robot protruding their tongues to the side of their mouths.

Human Infants' Preference for Face-Like Patterns and Conspecifics' Faces

Although newborn's visual acuity is known to be very rudimentary, humans are born with a functional contrast sensitivity system (Banks, & Salapateck, 1881; Fantz, 1961, Farroni, Johnson, Menon, Zulian, Faraguna, & Csibra, 2005; Slater, Earle, Morison, & Rose, 1985). Basically, newborns perceive the contrast between shadow and light, being capable of some form perception from birth, mainly if the stimuli is within 30 centimeters of them (Salter & Kirby, 1998; see von Hofsten, von Hofsten, Sulutvedt, Laeng, Brennen, Magnussen, 2014, for a simulation of infants form perception at various distances).

Newborns' form-perception competence, notably of facial traits, has been extensively investigated over the past 40 years (see Table 2). For instance, scholars have shown that newborns can discriminate between (a) familiar and unfamiliar faces (e.g., Walton & Bower, 1983), (b) female and male faces (e.g., Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002), (c) faces of different ethnicities (e.g., Sangrigoli & Schonen, 2004), (d) human and non-human primate faces (e.g., Heron-Delaney, Wirth, & Pascalis, 2011), and (e) their mother and other female faces (Pascalis, Schonen, Morton, Duruelle, Fabre-Grenet, 1995).

In addition to these differentiating abilities, newborns show a strong preference towards specific facial traits (see Table 2 for a summary of traits investigated). More importantly to the topic of this dissertation, newborns display a clear preference for face-like stimuli over scrambled or blank stimuli (Goren, Sarty, & Wu, 1975; Maurer & Barrera, 1981; Valenza, Simion, Machi-Cassia, & Umilta, 1996). This means that when newborns are shown two stimuli, one with an organization that resembles human face, e.g., ($\underline{{}^{+}|{}^{+}}$), and other whose organization is completely at random, e.g., (|__${}^{+}{}_{+}$), newborns look longer at the former, i.e., the face-like stimulus. More specifically, newborns' preference for face-like stimuli seems to be the result of an attraction to top-heavy stimuli (e.g., Leo & Simion, 2009; Macchi-Cassia, Turati, & Simion, 2004), and cues provided by the outer part of the faces, i.e., their contour (Turati, Macchi-Cassia, Simion, & Leo, 2006).

Despite this preference for face-like stimuli, neonates do not show any preference towards faces of their own species when given the option of also looking at a non-human primate face (Di Giorgio, Leo, Pascalis, & Simion, 2012; Kelly et al., 2005; Pascalis, de Haan, & Nelson, 2002; Sanefuji, Wada, Yamamoto, Mohri, Taniike, 2014). Independently of their ability to discriminate between human and other primate faces, neonates look equally long at a picture of a human face and a picture of a monkey paired together. It is only later, around the third month of age, that infants experience a perceptual narrowing, with their face-perception system becoming species- and ethnicity-specific. At that point, infants start to show preference in looking at humans faces over other primates, and at their own ethnicity over other ethnicity (Di Giorgio, Méary, Olivier, & Simion, 2013; Heron-Delaney, With, & Pascalis, 2011; Kelly et al., 2005; Sangrigoli, & de Schonen, 2004; Sanefujo, Wada, Yamamoto, Mohri, & Tanike, 2014).

A plausible explanation for this perceptual narrowing phenomenon is that neonates' face-perception system is shaped by exposure to faces in the first months of life (Di Giorgio et al., 2012, 2013; Sanefuji et al., 2014; Scott, Pascalis, & Nelson, 2007; Simpson, Varga, Frick, & Fragaszy, 2011; Slater et al., 2010). For example, there is a proposal that infants' face-recognition skills are supported by an experience-expectant brain system, whose sensitive period encompasses the first six months after birth; this hypothesis implies that neural processing underlying perception would undergo some specialization driven by infants' experience (Nelson, 2001). However, the amount of experience necessary, as well as the mechanisms involved in such narrowing is still unclear. For instance, it is unknown if exposure to few, or to many people has any impact on face-perception shaping.

In terms of imitation preferences, no study has yet compared newborns and infants reaction to humans' and apes' gestures. It is unknown if newborns and/or infants have a preference for imitating humans *versus*. apes. As mentioned before, such comparison would be a strong test of Meltzoff's (2005, 2007) *like-me* equivalence framework. If newborns and infants display a preference for imitating apes' over humans' gestures or do not display any preference, the *like-me* framework would need revision. On the contrary, if newborns and infants display a preference for the imitation of humans' over apes' gestures, the *like-me* framework would be further supported.

The lack of literature investigating infants' preference for imitating humans or more general face-like stimuli (e.g., apes) makes it difficult to predict infants' behaviour. However, if we connect the pieces of literature showing that (a) humans have an innate ability to imitate, as well as the ability to discriminate between human and other primate faces, and (b) that infants have a preference for face-like stimuli from birth, but only develop a conspecific preference by 3 months of age, we can hypothesize the following developmental trajectory:

- neonates match facial gestures of any face-like stimuli they see, i.e., they imitate humans' and apes' gestures, indistinctly, as newborns do not yet show a preference towards conspecific faces;

- while imitating other people's gestures throughout the first 3 months of age (and because there are more opportunities for infants to imitate people's and not apes' gestures), infants start to narrow down their primitive face-like perceptual system to a conspecific-face perceptual system; i.e., a preference for conspecific faces is developed;
- around the 3 months of age, a preference for conspecific faces is already established, and infants start to preferentially, and consistently, imitate their conspecifics' gestures over apes' gestures (one of the hypotheses tested in the current study). If true, this scenario suggests that by living together with other people infants identify and recognize themselves as similar to other people (*like-me* framework), and not to other non-human primates.

This developmental trajectory assumes that newborns are able to imitate from birth, and implies that humans might not be born ready to form *like-me* equivalences as proposed by Meltzoff (1999, 2005, 2007); or that infants might need to revise the equivalences established throughout infancy based on their social interactions. Through exposure to other people and the chance to imitate them, infants acquire the *like-me* understanding.

Whether the *like-me* correspondence is acquired in the first minutes of life, as claimed by Meltzoff (1999, 2005, 2007), or throughout the first months of infancy, imitation skills seem to be at its the core. As I discussed above, the evidence for humans' innate imitative skills was abundant in the 80s (see Table 1). Nonetheless, some researchers have criticized Meltzoff's assumptions (mainly the innateness of imitation) and have proposed different explanations for the observed matching between newborns and adults' facial expression (e.g., Jones, 2006; 2017; see Anisfeld, 1991, 1996, 2005 for a review).

Table 2

Summary of Studies Showing Evidence of Newborns and Infants' Preference for Face-Like Stimuli, Their Own Species and Ethnicity, Familiar Faces, and Their Mothers' Face

Study Reference	*N*	Age	Stimuli	Results
Goren et al., 1975	40	3 to 27 min	Face vs. Scrambled Face	Positive[1]
Maurer & Barrera, 1981	20; 18	1-2 months	Face vs. Scrambled Face	Positive for 2 months
Walton & Bower, 1983	16	8-72 hours	Composite Familiar vs. Unfamiliar Face	Positive
Field et al., 1984	48	~ 45 hours	Mother's vs. Stranger Face	Positive
Bushnell et al., 1989	40	~ 48 hours	Mother's vs. Stranger Face	Positive
Pascalis et al., 1995	34	72-120 hours	Mother's vs. Stranger Face	Positive
Valenza et al., 1996	20	25-155 hours	Face vs. Scrambled Face	Positive
Slater et al., 1998	16	14-151 hours	Attractive vs. Less-Attractive Face	Positive
Quinn et al., 2002	32	3-4 months	Female vs. Male Faces	Preference for female faces

Note: [1]Positive (opposite: negative)= evidence in favour of preference for face-like stimuli, own species and ethnicity, familiar face, attractive (symmetric) face, female face, and mothers' face.

Table 2 Continue

Study Reference	*N*	Age	Stimuli	Results
Pascalis et al., 2002	60	6-9 months	Human vs. Monkey Faces	Discrimination within both species by 6-month-olds
Simion et al., 2002	47	24-72 hours	Top-Heavy vs. Low-Heavy Patterns	Positive
Macchi-Cassia et al., 2004	20	25-73 hours	Top-Heavy vs. Low-Heavy Patterns	Positive
Sangrigoli & Schonen, 2004	18; 28	3 months	Same vs. Different Ethnic Group	Negative[2]
Farroni et al., 2005	61	13-168 hours	Top-Heavy vs. Low-Heavy Patterns	Positive
Kelly et al., 2005	38; 46	16-120 hours; 3 months	Same vs. Different Ethnic Group	Positive for 3 months
Sai, 2005	14	2-12 hours	Mother's vs. Stranger Face	Positive only if paired with voice

Note: [1]Positive (opposite: negative)= evidence in favour of preference for face-like stimuli, own species and ethnicity, familiar faces, attractive (symmetric) face, female face, and mothers' face.

Table 2 Continue

Study Reference	*N*	Age	Stimuli	Results
Quinn et al., 2008	20; 16	3 months; ~ 2.64 days	Female vs. Male Faces	Positive for 3 months
Leo & Simion, 2009	14	1-3 days	Top-Heavy vs. Low-Heavy Patterns	Positive
Heron-Delaney et al., 2011	18; 15; 16	~ 2.64 days; 3.5 months; 6 months	Human vs. Monkey Faces	Positive for 3 months
Di Giorgio et al., 2012	12	24-72 hours	Human vs. Monkey Faces	Negative
Di Giorgio et al., 2013	10	3 months	Human vs. Monkey Faces	Positive
Sanefuji et al., 2014	42; 66	1 month; 3 months	Human vs. Monkey Faces	Negative; Positive

Note: [1]Positive (opposite: negative)= evidence in favour of preference for face-like stimuli, own species and ethnicity, familiar faces, attractive (symmetric) face, female face, and mothers' face.

Critiques of Neonatal Imitation Research

Despite multiple studies showing that newborns can imitate (see Table 1), researchers have recently begun to question these findings (Heyes, 2016; Jones, 2016, 2017; Kennedy-Constantini, Slaughter, & Nielsen, 2017; Oostenbroek et al., 2016). Oostenbroek, Slaughter, Nielsen, and Suddendorf (2013) discuss how it is difficult to make an argument either in favour or against neonatal imitation abilities. The authors explain that such difficulty is due to the newborns' poor state regulation and visual system, as well as to a great methodological variation across studies. Besides, the authors mention the possible existence of a publication bias, in which only studies that find a positive evidence for neonatal imitation are published.

Perhaps, one of the greatest challenges to the theory of neonatal imitation are the results of a recent study published by Oostenbroek and colleagues (2016). The study counted with a sample of 106 infants, 64 of whom were longitudinally assessed at 1, 3, 6 and 9 weeks of age. Cross-sectionally, there were around 77-90 infants in each of these four time-points. Eleven gestures/movements were investigated: tongue protrusion, mouth opening, happy face, and sad face, a spoon protruding through a tube; a box opening; index finger protrusion, grasping, vocal gestures (''mmm,'' ''eee,'' and ''click'' sounds). Each gesture was presented for 60 seconds (4 trials of 15 seconds). The authors scored the number of the times the infants produced each of the gestures in each of the gesture conditions. Within gestures conditions, the authors did not find any evidence for imitation, i.e., the infants did not produce a higher frequency of the modelled gestures in contrast to the other gestures examined. When between conditions analyses were run, no gestures was found to be more frequent in its modelled condition than in all the other conditions (e.g., infants did not produce more tongue protrusion in the tongue protrusion condition than in all other conditions). Oostenbroek et al. thus concluded that there is no evidence for imitation in the first 9 weeks of age; the fact that previous studies found positive results for imitation is explained by methodological limitations and the possible existence of a publication bias (see also Heyes, 2016).

If human newborns are not capable of imitation, then, Meltzoff's (2005, 2007) explanation (*like-me* framework) that neonates have a *self-other* representation because they imitate is wrong. But how can we then explain Meltzoff and Moore's (1977, 1983, 1989, 1992, 1994) findings? As I discuss following, a few alternative explanations have been proposed in the past years.

Releasing mechanism. According to Jacobson (1979), newborns' movements are elicited by perceived movements, and not by an attempt to match adults' behaviour. In her experiment she had infants as young as 2- to 6-weeks exposed to tongue protrusion and withdrawal, hand opening and closing, a tennis ball and a black pen that were slowly moved towards and away from the infant, and an orange plastic ring moving up and down. Her findings showed that infants' frequency of tongue protrusion was not different in the tongue protrusion, the tennis ball, and the pen conditions. Also, no difference was found in the rate of infants' mouth opening behaviour in the hand and the ring conditions. Jacobson concludes that certain movements and forms triggers a reflex in newborns. For example, the fact that both tongue protrusion and a pen moving towards and away from infants' faces elicited tongue protrusion could indicate that newborns' sucking reflex was activated, meaning that anything that looks like a nipple and approaches newborns leads to them sticking out their tongues.

Abravanel and Sigafos (1984) and Anisfeld (1991, 1996, 2001) also advocate that neonatal imitation should be interpreted as a reflex. The authors found in their own studies, and in a meta-analysis, that newborns consistently imitate only tongue protrusion, and in order to claim that newborns are able to imitate, they needed to be able to imitate other gestures. In addition, infants tend to stop imitating tongue protrusion around 3 months of age, suggesting that infants were not voluntarily matching adults' behaviour (Heimann, 1989, 1998; Heimann, Nelson, & Schaller, 1989; Kugiumutzakis, 1999; Maratos, 1982).

The present study tried to replicate Jacobson's (1979) findings by exposing infants to both an experimenter modelling tongue protrusion, and a pen moving towards the infant. In addition, I investigated imitation longitudinally, from 5 days to 3 months of age as an attempt to see if imitation reliably drops by the end of this period.

Arousal and Pre-Reaching Exploratory Behaviour. A different explanation to neonatal imitation was proposed by Jones (1996, 2006). The author states that infants produce tongue protrusion and mouth opening whenever their interest is aroused. She supported her argument by showing that the frequency of infants' tongue protrusion increases every time they try to reach something in the environment, or whenever they are presented with an interesting stimuli (e.g., toy railway signal with coloured lights) in contrast to an uninteresting one (e.g., toy railway signal without coloured lights). Also, infants' frequency of tongue protrusion significantly dropped after they started reaching for objects. Thus, in Jones' perspective, infants' oral exploration is nothing more than a pre-reaching exploratory behaviour that reflects infants' engagement and motivation to explore, with real matching behaviour not appearing before 6 months of age (Jones, 2007).

I also tested Jones (1996, 2006) hypothesis. In the current study, infants saw an experimenter modelling tongue protrusion, a pen moving towards them, and an ape robot sticking its tongue. If neonatal tongue protrusion were an arousal reaction, infants would protrude their tongues more frequently when exposed to the ape robot (unfamiliar and complex stimuli) and the experimenter (unfamiliar but complex stimuli), than when exposed to the pen (simple stimuli) or to no stimuli (rest condition).

New Approaches to the Development of Imitation in Infancy

Faced with replication failures of neonatal imitation and the fact the newborns seem to imitate only a very restricted range of behaviours, Ray and Heyes (2011) have disputed Meltzoff and Moore's (1977, 1983) findings and have proposed a new theory of imitation development, *the associative sequence learning model*.

According to the associative sequence learning model a possible scenario is the following: the infant sees the mother doing A while s/he (infant) is also doing A. For example, in an interaction with his/her mother, if the infant sticks out a finger, and the mother imitates the infant's behaviour, she is helping the infant connect sensory and motor representations for that specific action. However, if in daily life, the infant keeps doing A and seeing the mother doing B, the infant learns to counter-imitate. For example, if the infant sticks out its finger and the mother holds up her arm, the infant will start to stick out the finger every time that s/he (infant) sees her/his mother holding up her arm. What prevents infants from learning to counter-imitate is their developmental environment, which provides the infants with more matching than with non-matching sensory-motor experiences (Ray & Heyes, 2011; Jones, 2016). Indeed, mothers seem to encourage infants' imitative behaviours (Zukow-Goldring & Arbib, 2007), as well as exaggerate their gestures so as to scaffold infants' imitative abilities (Brand, Baldwin & Ashburn, 2002). Infants' development environment also offers other imitation learning experiences, for instance, mirror self-observation and synchronous actions (Ray & Heyes, 2011). Thus, infants should differ in their imitative abilities depending on their developmental environment (e.g., the frequency of contiguous and contingent behaviours they are exposed to). In fact, Reeb-Sutherland, Levitti, and Fox (2012) showed that 1-month old infants' associative learning skills predicted their performance in imitative tasks later in infancy.

Similarly to Ray and Heyes (2011), Jones (2016, 2017) has also proposed a new theory for the development of imitation in infancy. While her framework draws heavily on Piaget's (1953, 1962) original theorization and description of imitation development (discussed above), she adds associative learning as the mechanism of developmental change throughout infancy. The maximum of Jone's theory is that imitation is learnt through the interaction with others, i.e., infants learn to imitate by being imitated. Following to Piaget's stages theory (1962), Jones (2016) proposes that imitation of transparent actions (i.e., actions that infants can see while executing) should emerge prior to imitation of opaque actions (i.e., facial gestures). Thus, infants might imitate more actions on objects during the first year, as well as actions they already know or can associate to a sensorial cue (e.g., sound). Imitation of novel and/or opaque actions is developed only in the second year of infancy. It is important to highlight that the present study does not directly test Jones' or Ray and Heyes' models. Nonetheless, if no evidence for neonatal imitation is found in the current study, these models offer possible explanations for that result.

The Current Study

Research Objective and Hypotheses

The overarching objective of this study was to test the *like-me* equivalence hypothesis (Meltzoff, 2005). The more specific objectives were as follows:

Objective 1. The first objective was to replicate and extend Meltzoff and Moore's (1994) findings on neonatal imitation. I wanted to replicate the authors' findings that infants around 1 and 2 months of age copy an adult's lateral protrusion, as well as to test if this is true of 3- to 7-day old newborns.

Goal. The specific goal was to investigate if newborns imitate humans' lateral tongue protrusion.

Hypothesis. Evidence for imitation is found if newborns imitate the tongue protrusion modelled by the experimenter. Although Meltzoff and Moore (1977, 1983, 1992; cf. Anisfeld et al., 2001; Oostenbroek et al., 2016) have previously found evidence for 6-week-olds imitation of forward tongue protrusion, newborns might not be equipped with the necessary motor skills to be capable of producing the lateral tongue protrusion yet; thus, no prediction was made regarding them. On the other hand, I expected that 1-, 2-, and 3-month old infants would copy the experimenter prompt of a lateral tongue protrusion.

Objective 2. This study's secondary objective was to investigate if newborns are biased toward imitating humans, or more broadly, face-like stimuli's gestures.

Goal. The specific goal was to investigate if newborns imitate human beings' and apes' lateral tongue protrusion by matching their behaviour.

Hypothesis. Even though some authors claim that neonatal imitation is evidence of newborns' conspecific identification capability (Meltzoff, 2005, 2007; Meltzoff and Gopnik, 1993; Tomasello, 1999; Rochat, 2003), there is no empirical evidence to support an innate bias toward conspecific imitation by human newborns. A predisposition toward face-like gesture imitation is supported if the newborns imitate both human's and ape's lateral tongue protrusion, but not an object simulation of the same behaviour. A bias to imitate human gestures is supported if the newborns imitate only human's modelling of a lateral tongue protrusion, but not the ape's or the object's simulation of that behaviour. More specifically, newborns would produce lateral tongue protrusion more frequently in the human condition and/or in the ape condition than in the object and the baseline condition.

Objective 3. This study's third objective was to investigate age-related changes in early imitation skills.

Goal. The specific goal was to investigate if newborns, 1-month, 2-month, and 3-month old infants differ in their preference for imitating humans' and apes' behaviour and objects' behavioural simulation.

Hypothesis. Similarly to other findings in the literature, newborns might display the ability to imitate human's facial gestures (e.g., Kaitz et al., 1988; Field et al., 1982, Meltzoff, & Moore, 1983, Nagy et al., 2013; Reissland, 1988; cf. Anisfeld et al., 2001; Oostenbroek et al., 2016), in the case of this study, to imitate a lateral tongue protrusion. If so, newborns should perform lateral tongue protrusion more frequently in the human condition than in the object and the baseline condition. The same finding should hold true for infants at 1, 2, and 3 months of age (Legerstee, 1991; Meltzoff & Moore, 1992, cf. Abravanel et al., 1984; Fontaince, 1984, Jacobson, 1979).

Regarding the comparison between the human and ape conditions, it is unclear if newborns will show any preference for imitating humans' over apes' behaviour. Newborns display a clear preference for face-like stimuli, over scrambled or blank stimuli (Goren et al., 1975; Leo, & Simion, 2009; Macchi-Cassia et al., 2004; Maurer, & Barrera, 1981; Slater et al., 1985; Slater, & Kirby, 1998; Simion et al., 2002; Valenza et al., 1996) and are able to distinguish between human and ape faces from birth (Di Giorgio et al., 2012). However, newborns do not show any preference toward faces of their own species when given the option of also looking at a non-human primate face (Di Giorgio et al., 2012; Kelly et al., 2005; Pascalis et al., 2002; Sanefuji et al., 2014). Such preference is seen only at 3-months of age (Di Giorgio et al., 2013; Heron-Delaney et al., 2011; Kelly et al., 2005; Sangrigoli, & de Schonen, 2004; Sanefujo et al., 2014; Slater et al., 2010).

Therefore, I hypothesized that newborns would imitate the tongue protrusion behaviour regardless if they saw a human or an ape modelling it. As a preference for human faces over non-human primates is developed within the first 3 months, we might witness a change in imitation preferences at three months of age. If so, infants should perform tongue protrusion more frequently when the experimenter models it, than when tongue protrusion is modelled by the ape robot.

Research Design and Method

In order to address the objectives described above, this study adopted an experimental and longitudinal design. Data were collected at 4 different time points, when infants were 3- to 7-day-old, 1 month-old, 2 month-old, and 3 month-old. The study is also descriptive, as I intended to investigate the developmental trajectory of imitation in infancy.

The choice to evaluate infants' matching skills in each of the four time points above is due to the fact that although infants can distinguish between human and ape faces from birth, it is only around 3 months that infants start to show conspecific preference (Di Giorgio et al., 2012; Di Giorgio et al., 2013; Sanefuji et al., 2014). Neonates have been shown to "imitate" humans' behaviors from 42 minutes to 6 weeks of age (Meltzoff, & Moore, 1977, 1983, 1992, 2002).

Participants

Ninety parents and their infants (49 females and 41 males) were recruited for this study. The mothers' age at infants' birth ranged from 22 to 42 years (*M* = 32.26; *SD* = 4.66). Gestational period varied from 37 to 42 weeks (*M* = 39.37; *SD* = 1.77), with the exception of two babies that were born on the 35th and 36th weeks of gestation. Aside from two mothers that had an emergency C-section, no other complications during birth were reported. According to the parents, Apgar scale indexes were all within the expected ranges. Out of the 90 pregnant women, 68 (75.5%) had a natural vaginal delivery, 1 (1.1%) had a vaginal delivery with the use of forceps, and 21 (23%) had C-sections. This sample is a representative of Alberta statistics. According to the Public Health Agency of Canada (2013), 27.7% of women in Alberta gave birth by cesarean in 2010-2011; Canada's overall average was 28.0%. At the time of the study, the participants were living in the greater Edmonton area.

Materials

Testing environment. In the first wave of data collection, I tried to collect data at the hospital, within 48 hours after birth (*N* = 10). However, the mothers participating in this study generally opted to have an epidural anesthesia, which can make the newborns very drowsy and hard to be kept awake. In 2011-2012, around 52.5% of the vaginal deliveries in Alberta were preceded by the use of epidural (Canadian Institute for Health Information, 2012). Newborns' bodies can take up to 48 hours to metabolize the anesthetic, and in some cases, it can take even longer (Murray, Dolby, Nation, & Thomas, 1981; Scanion, Brown, Weiss, & Alper, 1974). In view of that, I decided to change the first session of data collection from 3 to 7 days after birth, which happened at the participants' houses. The other three follow-up sessions also took place at the participants' houses.

Parents were allowed to be present during the experiment as long as they stayed out of neonate's visual field. Because I tested the infants at their houses, there were some surrounding noises that could not be avoided (e.g., older siblings playing, parents walking around, dogs barking, etc.). To deal with this background noise, I first attempted to put headphones on the newborns. However, I faced two challenges: (1) newborns would cry or be very upset as if bothered by the headphones; (2) some parents were not comfortable with the idea of their babies using the headphones. In view of these challenges, I decided to use a metronome application that ticked loudly through the whole experiment and masked surrounding noises.

Testing apparatus. The infant was placed down in a bassinet, on the floor/couch, in a car seat, or one of the parents held him/her 25 to 30 centimetres away from the experimenter/stimuli, this being the distance that newborns see best (von Hofsten et al., 2014). Two separated cameras, held by the same tripod, were used in this experiment (see Figure 1). Both cameras videotaped both the baby and the experimenter/stimuli. Originally I had intended to use one camera to videotape the baby and the other one to videotape the experimenter/stimuli. However, due to baby-experimenter/stimuli proximity, it was impossible not to have both videotaped. Finally, the metronome described above was also used to control the experiment timing.

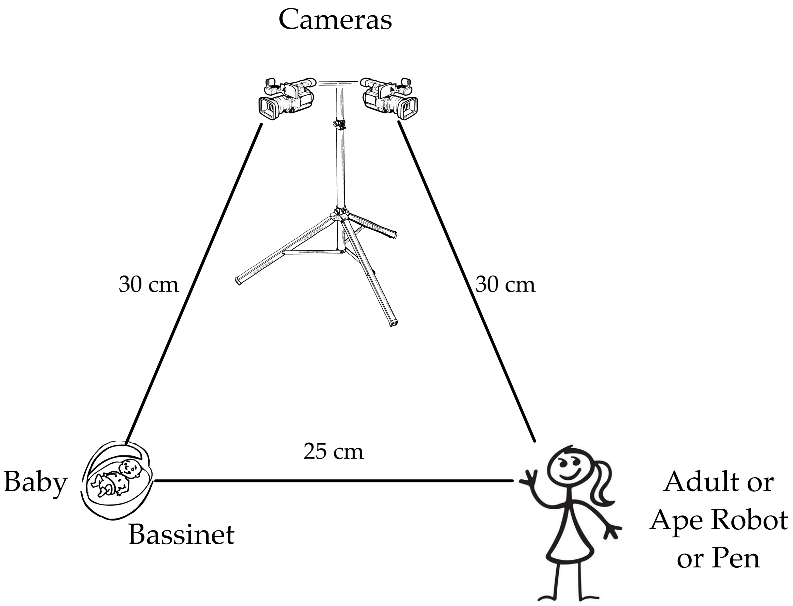

Figure 1. Experimental set-up.

Ape robot. A rubbery ape mask was used in the experiment. Mask circumferences dimensions were 78 centimeters (horizontal) by 72 centimetres (vertical). A rubber tongue was attached to the mask with a circuit that moved it laterally to both right and left sides (see Figure 2). The experimenter controlled tongue movement frequency and direction. A styrofoam mannequin head was used to fill out the mask and it was assembled in a tripod (see Figure 2).

Pen. A closed black felt-tip-pen of approximately 14 centimetres was used in the object condition described below (see Figure 2).

Figure 2. Ape robot and pen (sizes are not proportional).

Experimenter outfit. There were two experimenters: the author of this dissertation and a trained research assistant. The experimenters were always dressed with neutral colour clothing (e.g., black or pale colours) during the sessions and did not use glasses, ribbons, earrings, or anything that could distract infants from the target stimuli.

Procedure

Pregnant women were recruited at prenatal classes and through Facebook pages for mothers in Edmonton and surrounding area. In all cases, the mother signed an informed consent form allowing me to conduct the study with their babies. The mothers were asked to contact the experimenters once their babies were born to schedule the first study session. To facilitate the process, I sent weekly reminders by text to the mothers starting from 1 month before their due date.

The experiment was conducted at the participants' house within 3 to 7 days after birth and when the newborns completed 1 month of age, 2 months of age, and 3 months of age. The entire experimental session could take approximately 1 to 2 hours, depending on the newborn's state (e.g., aroused, sleepy, hungry, etc.). Parents received a $10.00 honorarium for each follow-up session (when the infants were 1, 2 and 3 months of age).

Although all the infants were visited in each of the 4 mentioned times, it was common, notably in the first two sessions, that the infant would be so sleepy that s/he could not be awakened; or sometimes, infants would cry for the whole time they were awake, making it impossible to run the experiment. After two hours at the mothers' house, the experimenters would leave even if they had not succeeded in collecting the data. The number of infants able to complete all sessions at each time point (i.e., up to 7 days after birth, 1, 2, and 3 months of age) was 51 (17 female infants), 74 (44 female infants), 79 (42 female infants) and 85 (46 female infants), respectively. Thirty-eight infants (20 female infants) completed all sessions at all time points. A session was considered complete if the infant focussed on the stimuli for at least 60 seconds (i.e., for at least 1 trial – see description below).

The infants were videotaped for 2 minutes in order to provide a baseline of their natural behaviours. For this part of the session, the experimenter was out of the infants' sight. After that, the infants participated in a within-subject experiment in which they were presented to three counterbalanced conditions: live human, ape robot, and object (pen). The side of tongue protrusion (right or left) for the first two conditions was also counterbalanced.

In all the conditions the metronome was used to override sounds in the environment and avoid infants' distraction. In each condition, before the experimenters began to model the tongue protrusion, they stood in front of the baby with a passive face for 20 seconds. In the *human* condition, infants saw a person doing the movement of tongue protrusion 45 degrees laterally to the centre of her mouth. The tongue protrusion movement (series of thrust and retrieval) lasted 20 seconds (totalling 10 thrusts), and was followed by a passive face also lasting 20 seconds.

This sequence (modelling-rest) was repeated three to five times, depending on infant's attentional state. In the *ape* condition, newborns were presented with the ape robot (see Figure 2), which also performed lateral tongue protrusions. Finally, in the *object* condition, the newborns saw a pen being moved slightly towards them (at an angle of 45 degrees) in order to simulate the lateral tongue protrusion movement. Both *ape* and *object* conditions followed the same pattern of 20 seconds of movement display, and 20 seconds of no movement, always initiating and ending the experiment with 20 seconds of no movement. The sequence (modelling-rest) was always repeated up to 5 times, depending on newborns' state.

Coding

The videos made were coded second by second. Infants' matching of the modelled behaviours was coded based on the procedures used by Meltzoff and Moore (1977, 1983, 1992, 2002), Jacobson (1979) and Jones (1996; see Table 3).

Baseline behaviour. Trained research assistants searched the 2-minute movie made in the beginning of the experiment for any lateral and straight tongue protrusion infants might perform.

Matching. The videos containing the newborns responses' to the three experimental conditions (human, ape, and object) were coded according to if the newborns matched the exact behaviour "lateral tongue protrusion" displayed (i.e., matched to tongue to tongue, independently if contralateral or absolute direction was matched).

Frequency measures. The frequency of infants' tongue protrusion was coded, i.e., how often the event occurred. Following Meltzoff and Moore's (2002) recommendation, infants' behaviour was considered evidence of tongue protrusion any time that there was forward or lateral thrust of the tongue that crosses the back edge of the lower lip. For the purpose of this study, tongue protrusion to the side of mouth midline, and forward tongue protrusion was considered separately.

Three pairs of independent research assistants coded 25% of all the data for reliability purposes. In all cases the coders were aware of the condition being coded but not of the study hypotheses. Intraclass correlation reliability coefficients for the tongue protrusion behaviours described on Table 3 ranged from .60 to .83 (Cronbach's alpha ranged from .59 to .84).

Table 3

Coding System

Tongue movement
1. Tongue at the level of the lower lip (inside the mouth)
(a) at midline, (b) to the left, (c) to the right
2. Tongue shortly extended (half or less of the tongue is seen)
(a) at midline, (b) to the left, (c) to the right
3. Tongue maximally extended (more than half of the tongue is seen)
(a) at midline, (b) to the left, (c) to the right

Infant state. Infants' state was coded following Nagy, Pilling, Orvos, and Molnar's study (2013): sleepy/sleeping (eyes closed, no movement), drowsy (eyes were half-closed, were frequently opened and closed, or only one eye could be seen in the movie), awake (both eyes were open and the baby seemed to be focused on the stimuli), and aroused/crying (baby overly active, crying, irritable, and disorganized gross-motor movements).

Three pairs of independent research assistants coded 25% of all the data for reliability purposes. Intraclass correlation reliability coefficients for infants' states ranged from .67 to .87 (Cronbach's alpha also ranged from .67 to .87).

Results

Data Screening and Treatment of the Data

Descriptive statistics for the raw data regarding tongue protrusion (i.e., absolute frequencies) can be found in Appendix A. An initial screening of the data indicated the need for some adjustments to the variables before any analyses could be conducted.

As can be seen on the tables in Appendix A, short and long tongue protrusions were very infrequent and the variance within these categories was very low across the 4-time points. For these reasons, these two categories were collapsed. Similarly, lateral tongue protrusion was also extremely rare in the data set (see Appendix A). Thus, lateral tongue protrusion to right and left sides were also added together.

Regarding infants' states, drowsy and awake were added together. The reasoning for that is that the drowsy category encompassed several moments where one of the infants' eyes was partially blocked in the movies by some object or even the camera angle. However, the other eye shown in the video was generally wide open. In addition, because the data were coded second by second, whenever infants were blinking, it was coded as drowsy. Finally, sleepy and aroused/crying were added together as these two states indicate that the infants were not paying attention to the stimuli presented to them and therefore could not be imitating it.

To control for individual differences and the duration of each condition, the total frequency of tongue protrusion within each experimental condition was divided by that condition duration for each infant. The resulting proportions (frequency of tongue protrusions by second), and not the raw frequency, were used in the analyses below.

Table 4

Descriptive Statistics at Time 1 (*M*= 3.67 days of age; *SD*=1.38 days)

	Human		Pen		Ape		Baseline	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Duration (minutes)	3.53 (1.45)	1.00 - 8.45	3.11 (.92)	1.00 - 6.07	3.36 (0.93)	1.12 - 6.07	2.20 (.47)	1.30 - 3.37
Proportion[a] of Infants' State								
Sleep/Aroused	.30 (.23)	.01 - .90	.34 (.25)	.01 - .90	.31 (.24)	.02 - .79	.48 (.32)	.00 – 1.00
Awake/Drowsy	.70 (.23)	.01 - .99	.66 (.25)	.09 - .99	.69 (.24)	.21 - .98	.52 (.32)	.00 – 1.00
Proportion for Tongue at Midline								
Inside mouth	.08 (.13)	.00 - .87	.08 (.09)	.00 - .47	.06 (.07)	.00 - .32	.12 (.15)	.00 - .67
Short/Long (Forward)	.02 (.03)	.00 - .16	.02 (.03)	.00 - .10	.02 (.03)	.00 - .20	.03 (.06)	.00 - .26
Proportion for Tongue to the Side								
Inside mouth	.00 (.01)	.00 - .03	.00 (.00)	.00 - .02	.00 (.01)	.00 - .03	.00 (.01)	.00 - .03
Short/Long (Lateral)	.00 (.00)	.00 - .01	.00 (.00)	.00 - .02	.00 (.01)	.00 - .10	.00 (.02)	.00 - .13

N= 51 (Male= 24; Female = 27); [a]total frequency within each experimental condition divided by the condition time duration

Table 5

Descriptive Statistics at Time 2 (*M*= 30.57 days od age*; SD*= 3.01 days)

	Human		Pen		Ape		Baseline	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Duration (minutes)	3.75 (1.64)	1.00 - 9.57	3.46 (1.03)	1.72 - 7.42	3.72 (1.40)	1.57 - 9.22	2.27 (.59)	1.05 - 4.37
Proportion[a] of Infants' State								
Sleep/Aroused	.21 (.19)	.00 – .90	.19 (.17)	.00 - .76	.22 (.19)	.00 - .83	.21 (.24)	.00 – 1.00
Awake/Drowsy	.79 (.19)	.01 – 1.00	.78 (.23)	.23 – 1.79	.78 (.19)	.17 – 1.00	.79 (.24)	.00 – 1.00
Proportion for Tongue at Midline								
Inside	.10 (.12)	.00 - .85	.10 (.11)	.00 - .58	.11 (.11)	.00 - .58	.10 (.12)	.00 - .85
Short/Long (Forward)	.05 (.08)	.00 - .57	.04 (.07)	.00 - 46	.04 (.06)	.00 - .36	.05 (.08)	.00 - .57
Proportion for Tongue to the Side								
Inside	.00 (.01)	.00 - .04	.00 (.01)	.00 - .04	.00 (.01)	.00 - .05	.00 (.01)	.00 - .04
Short/Long (Lateral)	.00 (.01)	.00 - .04	.00 (.01)	.00 - .05	.00 (.01)	.00 - .09	.00 (.01)	.00 - .04

N= 74 (Male= 30; Female= 44); [a]total frequency within each experimental condition divided by the condition time duration.

Table 6

Descriptive Statistics at Time 3 (*M*= 61.13 days of age; *SD*= 3.88 days)

	Human		Pen		Ape		Baseline	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Duration (minutes)	4.13 (1.01)	2.18 - 8.02	3.57 (.54)	1.68 - 5.62	3.76 (.71)	1.83 - 5.78	2.37 (.68)	1.68 - 4.80
Proportion[a] of Infants' State								
Sleep/Aroused	.13 (.20)	.00 - .90	.08 (.12)	.00 - .70	.11 (.14)	.00 - .67	.08 (.14)	.00 - .72
Awake/Drowsy	.87 (.20)	.01 – 1.00	.92 (.12)	.30 – 1.00	.89 (.14)	.33 – 1.00	.92 (.14)	.28 – 1.00
Proportion for Tongue at Midline								
Inside	.08 (.09)	.00 - .47	.06 (.09)	.00 - .59	.08 (.07)	.00 - 41	.06 (.09)	.00 - .38
Short/Long (Forward)	.03 (.04)	.00 - .17	.02 (.04)	.00 - .21	.02 (.04)	.00 - .19	.03 (.05)	.00 - 31
Proportion for Tongue to the Side								
Inside	.00 (.00)	.00 - .01	.00 (.00)	.00 - .02	.02 (.04)	.00 - .19	.00 (.00)	.00 - .02
Short/Long (Lateral)	.00 (.01)	.00 - .04	.00 (.01)	.00 - .04	.00 (.01)	.00 - .06	.00 (.01)	.00 - .04

N= 79 (Male= 37; Female= 42); [a]total frequency within each experimental condition divided by the condition time duration.

Table 7

Descriptive Statistics at Time 4 (*M*= 90.02 days od age; *SD*= 3.03 days)

	Human		Pen		Ape		Baseline	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Duration (minutes)	3.93 (1.14)	2.00 - 8.45	3.50 (.48)	2.02 - 4.32	3.80 (1.01)	2.05 - 8.98	2.18 (.53)	1.00 - 4.10
Proportion[a] of Infants' State								
Sleep/Aroused	.09 (.16)	.00 - .90	.05 (.09)	.00 - .62	.07 (.11)	.00 - .57	.05 - .12	.00 - .81
Awake/Drowsy	.91 (.16)	.02 – 1.00	.95 (.09)	.38 – 1.00	.93 (.11)	.43 – 1.00	.95 (.12)	.19 – 1.00
Proportion for Tongue at Midline								
Inside	.09 (.09)	.00 - .51	.06 (.09)	.00 - .55	.09 (.11)	.00 - .54	.08 (.13)	.00 - .62
Short/Long (Forward)	.03 (.04)	.00 - .21	.02 (.03)	.00 - .16	.04 (.07)	.00 - .40	.03 (.05)	.00 - .31
Proportion for Tongue to the Side								
Inside	.00 (.01)	.00 - .05	.00 (.00)	.00 - .02	.00 (.01)	.00 - .04	.00 (.01)	.00 - .05
Short/Long (Lateral)	.00 (.01)	.00 - .05	.00 (.01)	.00 - .04	.01 (.02)	.00 - .10	.01 (.01)	.00 - .08

N= 85 (Male= 39; Female= 46); [a]total frequency within each experimental condition divided by the condition time duration.

Descriptive Statistics

The mean proportion, standard deviation and range (minimum and maximum) for the proportions of tongue protrusion and infants' state, in each of the 4-time points, can be found in Tables 4-7 above. For the purpose of this study, it is important to highlight that at all time points, the average infant was awake/drowsy for at least half of each condition. Also, the mean proportion of time awake/drowsy significantly increased across time (see Figure 3), $F(3, 35) = 14.86$, $p < .001$. Tukey HSD post-hoc test resulted statistically significant for all the pairwise comparisons, *ps* < .05.

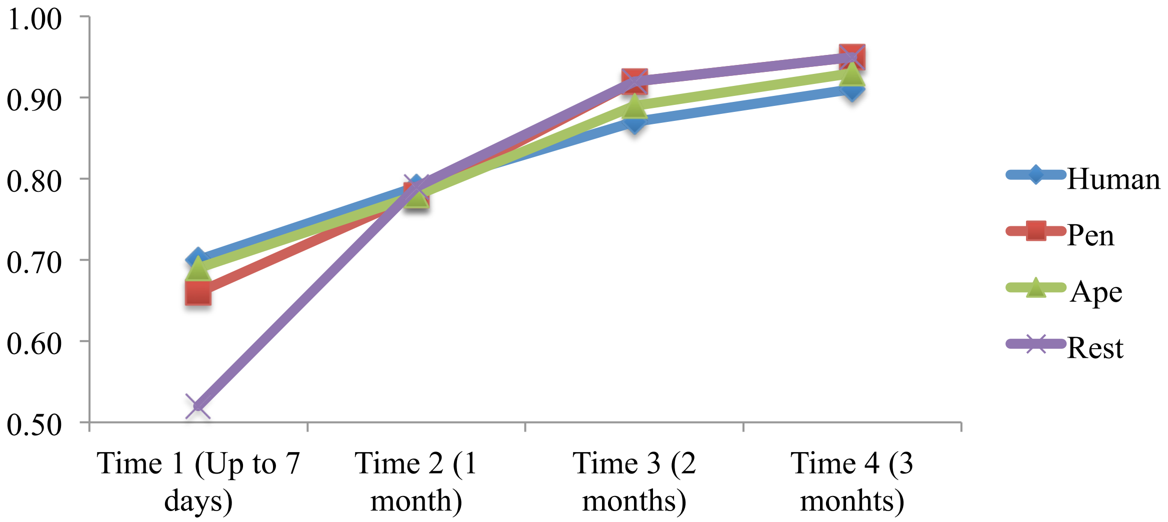

Figure 3. Mean proportion of time awake/drowsy across time.

The tongue protrusion behaviour is depicted as frequency by second in the Tables 4-7. In general, tongue protrusions were very infrequent. Forward tongue protrusions were extremely rare, and lateral tongue protrusions were almost nonexistent (the mean proportions across time were virtually zero, and the standard deviations were quite low, varying from .00 to .02). Most of the time the infants' tongue was seating inside their mouths, at the midline (means varying from .06 to .12 across time).

As can be seen in Table 8 (see also Figures 5 to 8 below), across time, only a maximum of 33% of the infants happened to exhibit any lateral tongue protrusion. In comparison, a maximum 80% of the infants displayed at least one instance of forward tongue protrusion.

Table 8

Percentage of Infants who Never Exhibited Tongue Protrusion, by Condition and Time

	Human	Pen	Monkey	Baseline
Time 1 (up to 7 days)				
Forward TP	47%	43%	33%	42%
Lateral TP	84%	86%	84%	88%
Time 2 (1 month)				
Forward TP	20%	23%	23%	40%
Lateral TP	70%	74%	69%	81%
Time 3 (2 months)				
Forward TP	24%	30%	32%	39%
Lateral TP	76%	84%	81%	84%
Time 4 (3 months)				
Forward TP	27%	37%	28%	46%
Lateral TP	81%	75%	67%	74%

Note: TP = tongue protrusion

Due to the low frequency of tongue protrusion, I tested the data against the normal distribution. Results from one-sample Kolmogorov-Smirnov test showed that my variables were not normally distributed (*ps* < .05). Because of such findings, and the low interindividual variance in the data, only non-parametric statistical tests were used in the following analyses.

Stability Analyses

I used Spearman's rho correlation test to investigate inter-individual stability across conditions and across time. I wanted to know if the infants with higher proportion of tongue protrusions were the same ones across conditions and time. Thus, infants' lateral and forward tongue protrusions were the variables used in the following analyses.

Time 1 (up to 7 days; *N*=51). Regarding the proportion of lateral tongue protrusions across conditions (human, pen, ape, and baseline), I found a weak to moderate stability; correlation coefficients ranged from .264 to .548, *ps* < .06. The same was true of forward tongue protrusion; correlation coefficients ranged from .363 to .506, *ps* < .009.

Time 2 (1 month; *N*=74). I also found a weak to moderate stability for the proportion of lateral tongue protrusions across conditions in time 2. Correlation coefficients ranged from .291 to .526, *ps* <. 012. Interindividual differences for the proportion of forward tongue protrusions seemed to be moderately stable across conditions; correlation coefficients ranged from .553 to .613, *ps* < .001

Time 3 (2 months; *N*=79). At the third data wave, correlation coefficients for the proportion of lateral tongue protrusions were of moderate strength, ranging from .499 to .607, *ps* < .001. Coefficients for the proportion of forward tongue protrusions were of weak to moderate strength, ranging from .343 to .624, *ps* < .002.

Time 4 (3 months; *N*=85). Correlation coefficients for both the proportion of lateral and forward tongue protrusions indicated that there was weak to moderate interindividual stability across conditions; coefficients ranged, respectively, from .220 to .472, *ps* < .043, and from .394 to 601, *ps* < .001.

Across time. Taking the (1) human condition, correlation coefficients for both the proportion of lateral and forward tongue protrusions were of weak to moderate strength, ranging from .245 to .594, *ps* < .10, and from .242 to .499, *ps* < .10, respectively.

For the (2) pen condition, correlation coefficients were of weak strength for the proportion of lateral tongue protrusions, ranging .062 to .349 *ps* > .032. Forward tongue protrusion coefficients ranged from .241 to .526, *ps* < .10.

Results for the (3) ape condition were similar, with correlation coefficients showing weak to moderate stability across time. Lateral and forward tongue protrusion correlation coefficients ranged from .240 to .508, *ps* < .10, and .08 to .452, .004 < *ps* < .601, respectively.

Lastly, the (4) baseline condition was also analysed. Correlation coefficients for the proportion of lateral tongue protrusions were weak, ranging from .045 to .227, *ps* > .170. On the other hand, I found moderate correlation coefficients for the proportion of forward tongue protrusions, which ranged from .419 to .623, *ps* < .009.

In the next two sections, I am going to describe both cross-sectional (between conditions) and longitudinal (within conditions) analyses of the current data, respectively.

Cross-sectional analyses

Time 1 (up to 7 days; *N*=51). The proportion of lateral and forward tongue protrusions for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 126.686$, $p < .001$. These findings indicated an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue protrusions** between the human, pen, ape and baseline condition. The results indicated that none of the pairwise comparisons were statistically significant, $Zs < 1.511$, $ps > .131$; i.e., the conditions did not differ from each other.

The same analyses were done for the proportion of **forward tongue protrusions**. I found a statistical significant difference between the human and the baseline condition, $Z = 2.105$ $p = .035$; the ape and the baseline condition, $Z = 2.268$, $p = .023$; and a marginally significant difference between the pen and the baseline condition, $Z = 1.821$, $p = .069$. In all the cases, there were more forward tongue protrusions in the baseline condition than in the other three conditions.

I also compared lateral tongue protrusion to forward tongue protrusion within each condition. Results showed that for all the cases the proportion of forward tongue protrusions was higher than the proportion of lateral tongue protrusions, $Zs > 4.465$, $p < .001$.

Finally, the proportion of lateral and midline tongue inside the mouth for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 228.281$, $p < .001$. These findings indicate an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue inside the mouth** between the human, pen, ape and baseline condition. The results showed that none of the pairwise comparisons were statistically significant, $Zs < 1.136$, $ps > .256$; i.e., the conditions did not differ from each other.

I also compared lateral tongue inside the mouth and tongue at midline inside the mouth within each condition. Results showed that for all the cases the proportion of tongue at midline inside the mouth was higher than the proportion of lateral tongue inside the mouth, *Zs* > 5.841, *p* < .001.

Time 2 (1 month; *N*=74). The proportion of lateral and forward tongue protrusions for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 235.552$, $p < .001$. These findings indicated an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue protrusions** between the human, pen, ape and baseline condition. The results indicated that none of the pairwise comparisons were statistically significant, *Zs* < 1.187, *ps* > .184; i.e., the conditions did not differ from each other.

The same analyses were done for the proportion of **forward tongue protrusions**. The results indicated that none of the pairwise comparisons were statistically significant, *Zs* < 1.415, *ps* > .157; i.e., the conditions did not differ from each other.

I also compared lateral tongue protrusion to forward tongue protrusion within each condition. Results showed that for all the cases the proportion of forward tongue protrusions was higher than the proportion of lateral tongue protrusions, *Zs* > 5.751, *p* < .001.

Finally, the proportion of lateral and midline tongue inside the mouth for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 340.912$, $p < .001$. These findings indicate an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue inside the mouth** between the human, pen, ape and baseline condition. The results indicated that none of the pairwise comparisons were statistically significant, *Zs* < 1.085, *ps* > .278; i.e., the conditions did not differ from each other.

I also compared lateral tongue inside the mouth and tongue at midline inside the mouth within each condition. Results showed that for all the cases the proportion of midline tongue inside the mouth was higher than the proportion of lateral tongue inside the mouth, *Zs* > 6.955, *p* < .001.

Time 3 (2 months; *N*=79). The proportion of lateral and forward tongue protrusions for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 226.470$, $p < .001$. These findings indicated an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue protrusions** between the human, pen, ape and baseline condition. The results indicated that none of the pairwise comparisons were statistically significant, *Zs* < 1.034, *ps* > .301; i.e., the conditions did not differ from each other.

The same analyses were done for the proportion of **forward tongue protrusions**. The results indicated that none of the pairwise comparisons were statistically significant, *Zs* < 1.405, *ps* > .162; i.e., the conditions did not differ from each other.

I also compared lateral tongue protrusion to forward tongue protrusion within each condition. Results showed that for all the cases the proportion of forward tongue protrusions was higher than the proportion of lateral tongue protrusions, *Zs* > 5.969, *p* < .001.

Finally, the proportion of lateral and midline tongue inside the mouth for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 354.018$, $p < .001$. These findings indicate an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue inside the mouth** between the human, pen, ape and baseline condition. The results indicated that the ape condition was significantly different from the human condition, the pen condition and the baseline condition, $Z = .5.874$, $p < .001$, $Z = 5.760$, $p < .001$, $Z = 6.121$, $p < .001$, respectively. In all the cases there was more lateral tongue inside the mouth in the ape condition. None of other the pairwise comparisons were statistically significant, *Zs* < .900, *ps* > .368.

I also compared lateral tongue inside the mouth and midline tongue inside the mouth within each condition. Results showed that for all the cases the proportion of tongue at midline inside the mouth was higher than lateral tongue inside the mouth, *Zs* > 6.275, $p < .001$.

Time 4 (3 months, *N*=85). The proportion of lateral and forward tongue protrusions for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 167.102$, $p < .001$. These findings indicated an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue protrusions** between the human, pen, ape and baseline condition. The results indicated that the human condition was different from the ape condition, $Z = 3.467$, $p = .001$, the baseline condition, $Z = 3.155$, $p = .002$, and the pen condition, $Z = 1.634$, $p = .102$, although the last comparison reached only marginally significance. There was a higher proportion of lateral tongue protrusions in the ape, in the pen, and in the baseline condition than in the human condition. The other comparisons were not statistically significant, *Zs* < 1.291, *ps* > .197.

The same analyses were done for the proportion of **forward tongue protrusions**. I found a statistical significant difference between the human and the pen condition, $Z = 2.383$ $p = .017$;

and the ape and the pen condition, $Z = 2.906$, $p = .004$. In all the cases, there was a lower proportion of forward tongue protrusions in the pen condition than in the other two conditions. The other comparisons were not statistically significant, $Zs < 1.498$, $ps > .134$.

I also compared lateral tongue protrusion to forward tongue protrusion within each condition. Results showed that for all the cases the proportion of forward tongue protrusions was higher than the proportion of lateral tongue protrusions, $Zs > 4.969$, $p < .001$.

Finally, the proportion of lateral and midline tongue inside the mouth for each condition was compared through the Friedman Test, which was statistically significant, $X^2(7) = 405.200$, $p < .001$. These findings indicate an overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue inside the mouth** between the human, pen, ape and baseline condition. I found a marginally significant difference between the ape and the pen condition, $Zs = 1.680$, $ps = .093$; there was a higher proportion of lateral tongue inside the mouth in the ape condition than in the pen one. None of the other pairwise comparisons were statistically significant, $Zs < .982$, $ps > .326$; i.e., the conditions did not differ from each other.

I also compared lateral tongue and midline tongue inside the mouth within each condition. Results showed that for all the cases the proportion of midline tongue inside the mouth was higher than the proportion of lateral tongue inside the mouth, $Zs = 7.207$, $p < .001$.

Longitudinal analyses

Human condition (*N*=38). The proportion of lateral tongue protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 2.843$, $p = .416$. Similar results were found for the proportion of lateral tongue inside the mouth across time, $X^2(3) = .569$, $p = .903$. These findings indicated that there was no difference in the proportion of lateral tongue protrusions and lateral tongue inside the mouth longitudinally.

Regarding the proportion of forward tongue protrusions and of midline tongue inside the mouth, I also did not find any differences within these two categories across time, $X^2(3) = 4.837$, $p = .184$, and $X^2(3) = 1.984$, $p = .576$, respectively.

Ape condition (*N*=38). The proportion of lateral tongue protrusions for each time point was compared through the Friedman Test, which was statistically significant, $X^2(3) = 8.196$, $p = .042$. Pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate further this finding. Significant differences were found between the proportion of lateral tongue protrusions at times 3 and 2, and at times 4 and 3, $Z = 2.341$, $p = .019$, and $Z = 2.132$, $p = .033$, respectively. There was a higher proportion of lateral tongue protrusions at time 2 (1 month) and time 4 (3 months) than at time 3 (2 months). On the other hand, I did not find any significant difference between the proportion of lateral tongue inside the mouth across time when using the Friedman Test, $X^2(3) = 3.642$, $p = .303$.

Regarding the proportion of forward tongue protrusions and of midline tongue inside the mouth, I also did not find any differences within these two categories across time, $X^2(3) = 1.326$, $p = .723$, and $X^2(3) = 4.723$, $p = .193$, respectively.

Pen condition (*N*=38). The proportion of lateral tongue protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = .766$, $p = .857$. Similar results were found for the proportion of lateral tongue inside the mouth across time, $X^2(3) = 3.023$, $p = .388$. These findings indicated that there was no difference in the proportion of lateral tongue inside the mouth longitudinally.

Regarding the proportion of forward tongue protrusions, I also did not find any differences within the pen condition across time, $X^2(3) = .994, p = .803$. However, I found a significant difference in the proportion of midline tongue inside the mouth across time, $X^2(3) = 8.905, p = .031$. Pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate further this finding. Significant differences were found between the proportion of midline tongue inside the mouth at time 2 (1 month) and time 3 (2 months), and at time 2 (2 months) and time 4 (3 months), $Z = 2.850, p = .004$, and $Z = 3.009, p = .003$, respectively. There was a higher proportion of midline tongue inside the mouth at time 2 (1 month) than at times 3 (2 months) and 4 (3 months).

Baseline condition (*N*=38). The longitudinal comparisons, within the baseline condition, resulted as not statistically significant: $X^2(3) = 4.912, p = .173$, for lateral tongue protrusion; $X^2(3) = .213, p = .976$, for lateral tongue inside the mouth; $X^2(3) = 3.333, p = .343$, for forward tongue protrusion; and $X^2(3) = 2.776, p = .427$, for midline tongue inside the mouth.

Analyses for Forward and Lateral Tongue Protrusion Added together

To investigate the arousal/pre-reaching behaviour theory (i.e., increase in the frequency of tongue protrusion as a sign of interest; Jones, 1996), as well as the releasing mechanism hypothesis (i.e., increase in the frequency of tongue protrusion as a sign of instinctive behaviour; Jacobson, 1979), the same cross-sectional and longitudinal analyses for **lateral plus forward tongue protrusion** (from now on tongue protrusion) were done again. Cross-sectional analyses are illustrated in Figure 4 below.

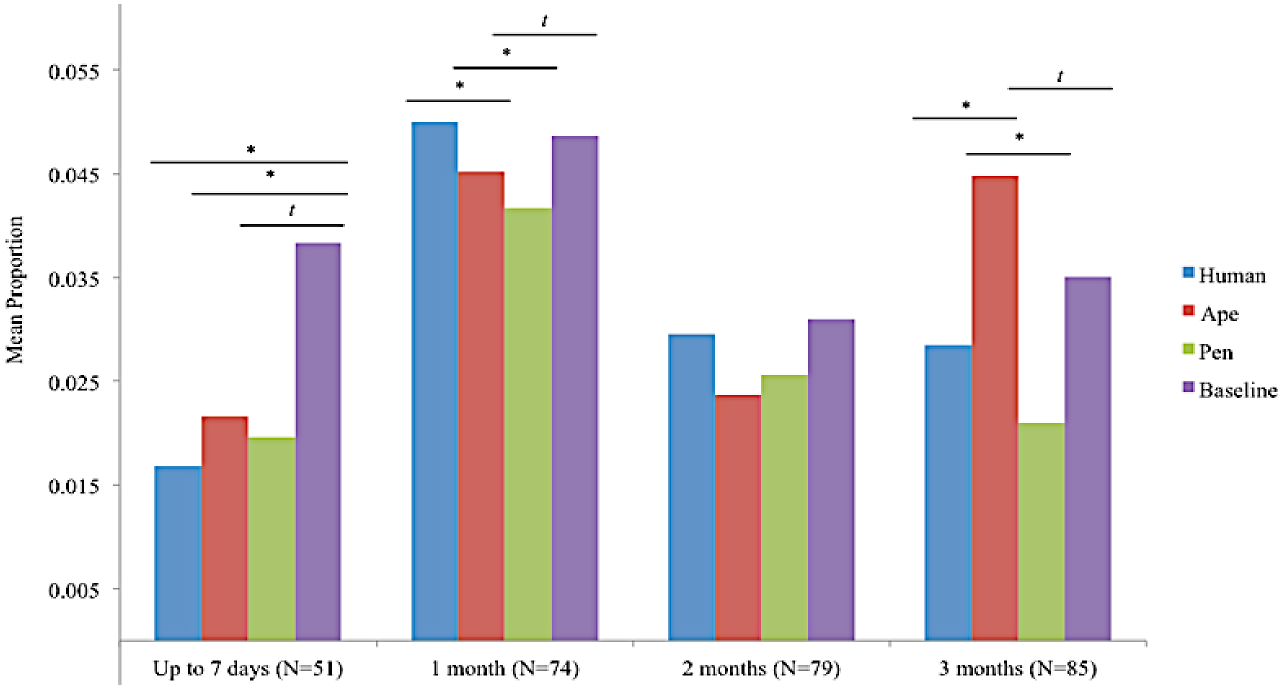

Figure 4. Mean proportion of **lateral plus forward tongue protrusions**. *Note:* *$p < .05$; $^t p < .10$.

Cross-sectional analyses. Time 1 (up to 7 days; *N*=51). The proportion of tongue protrusions for each condition was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 2.912$, $p = .405$; i.e., there was no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between conditions. I found a statistical significant difference between the baseline and the human condition, $Z = 2.009$, $p = .045$; the baseline and the ape condition, $Z = 2.086$, $p = .037$; and a marginally significant difference between the baseline and the pen condition, $Z = 1.863$, $p = .062$. The proportion of tongue protrusions in the baseline condition was higher than all the other conditions.

Cross-sectional analyses. Time 2 (1 month; *N*=74). The proportion of tongue protrusions for each condition was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 2.129$, $p = .546$; i.e., there was no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between conditions. I found a statistical significant difference between the ape and the human condition, $Z = 1.972$, $p = .049$; the ape and the pen condition, $Z = 3.239$, $p = .001$; and a marginally significant difference between the pen and the baseline condition, $Z = 1.715$, $p = .086$. The human condition had a higher proportion of tongue protrusion than the ape condition; the ape and the baseline condition had a higher proportion of tongue protrusions than the pen condition.

Cross-sectional analyses. Time 3 (2 months; *N*=79). The proportion of tongue protrusions for each condition was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 1.306$, $p = .728$. These findings indicated that there is no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between conditions. I did not find any significant difference between the conditions, *Zs* < 1.368, *ps* > .171.

Cross-sectional analyses. Time 4 (3 months; *N*=85). The proportion of tongue protrusions for each condition was compared through the Friedman Test, which was only marginally significant, $X^2(3) = 6.443$, $p = .092$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between conditions. I found a statistical significant difference between the ape and the human condition, $Z = 1.972$, $p = .049$; the ape and the pen condition, $Z = 3.239$, $p = .001$; and a marginally significant difference between the pen and the baseline condition, $Z = 1.715$, $p = .086$. The ape condition had a higher proportion of tongue protrusions than the human condition and the pen condition; similarly, the baseline condition had a higher proportion of tongue protrusions than the pen condition.

Longitudinal analyses. Human condition (*N*=38). The proportion of tongue protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 4.014$, $p = .260$; i.e., there was no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between time points. No significant result was found, $Zs < 1.720$, $p > .116$.

Longitudinal analyses. Ape condition (*N*=38). The proportion of tongue protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 2.006$, $p = .571$; i.e., there was no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between time points. No significant result was found, $Zs < 1.384$, $p > .166$.

Longitudinal analyses. Pen condition (*N*=38). The proportion of tongue protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 1.314$, $p = .726$; i.e., there was no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between time points. No significant result was found, $Zs < 1.097$, $p > .272$.

Longitudinal analyses. Baseline condition (*N*=38). The proportion of tongue protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 4.414$, $p = .220$; i.e., there was no overall difference between the conditions.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run to investigate possible differences between time points. No significant result was found, $Zs < 1.417$, $p > .156$.

Analyses for Infants with at least One Instance of Lateral Tongue Protrusion

In an attempt to further investigate imitative behaviours, the same cross-sectional and longitudinal analyses for **lateral tongue protrusion** were completed again. However, this time only the data of infants who had at least one event of lateral tongue protrusion in the human and/or in the ape condition was used (see Figures 5 to 8 below). The cross-sectional analyses are illustrated in Figure 9 below.

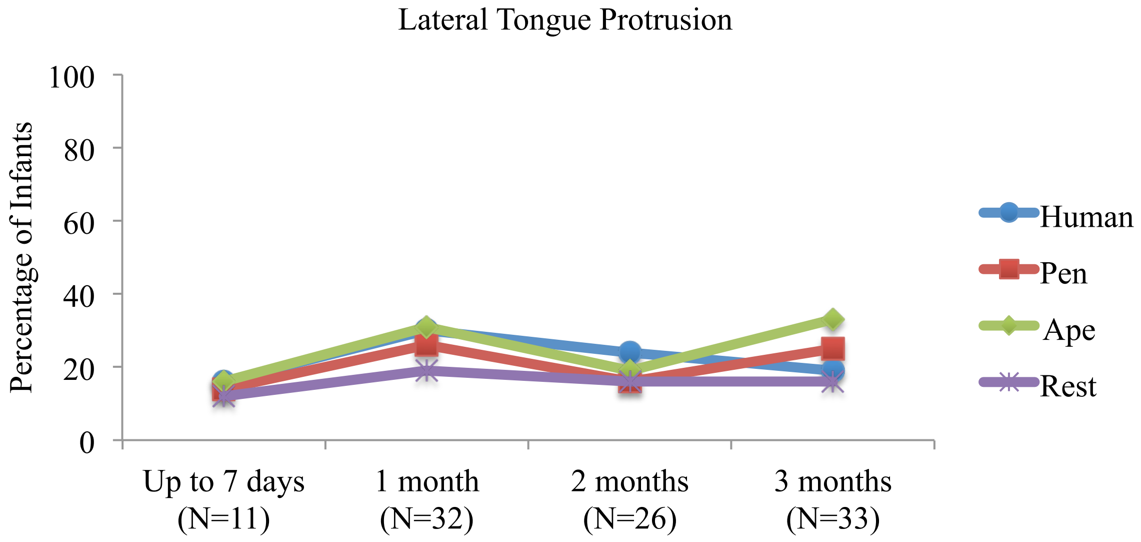

Figure 5. Percentage of infants with at least one instance of **lateral tongue protrusion**.

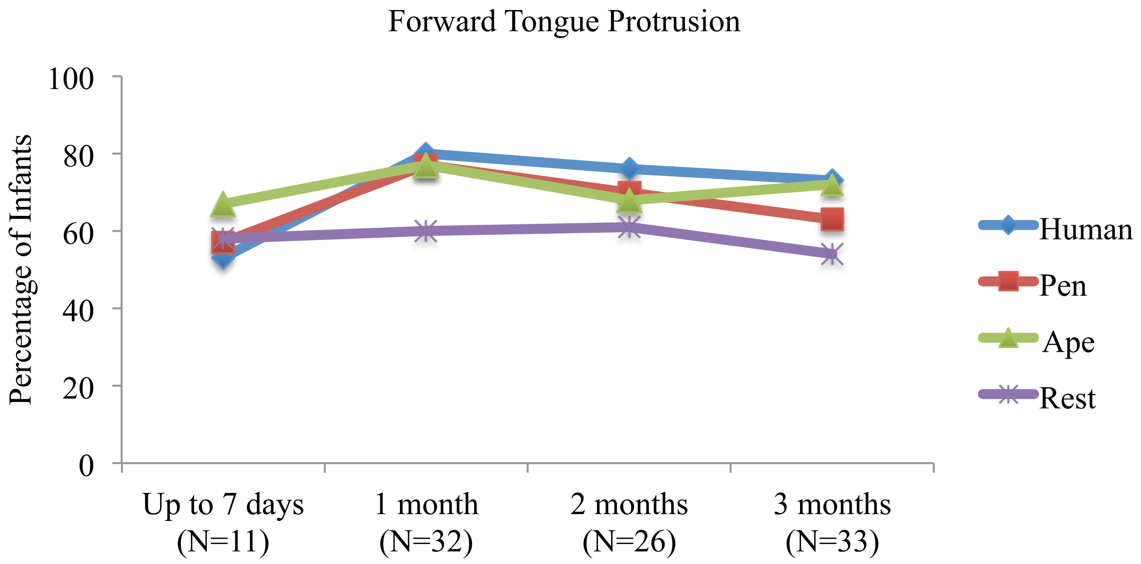

Figure 6. Percentage of infants with at least one instance of **forward tongue protrusion**.

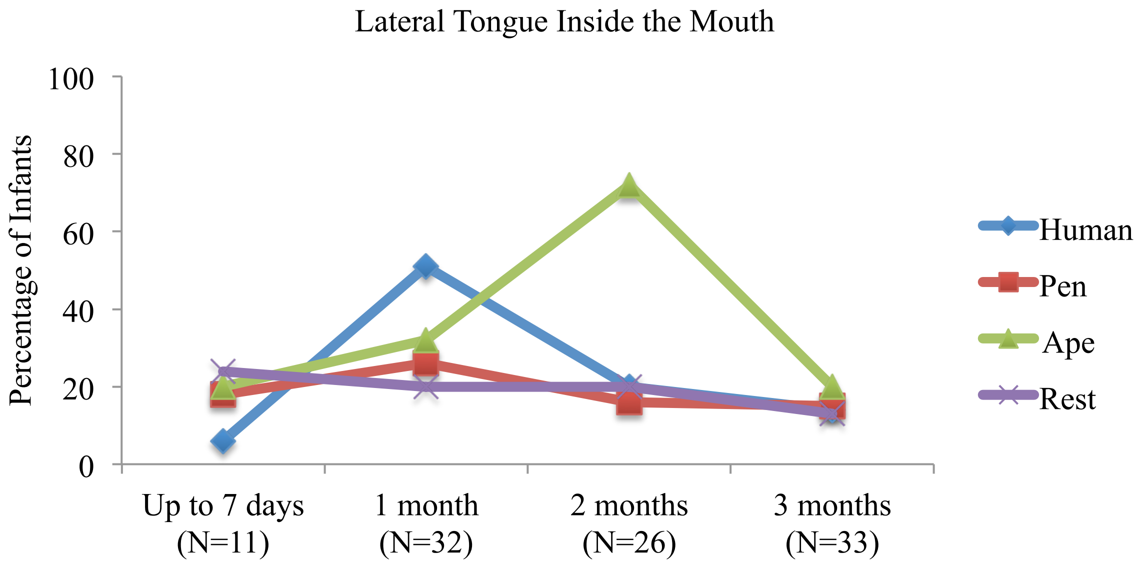

Figure 7. Percentage of infants with at least one instance of **lateral tongue inside the mouth**.

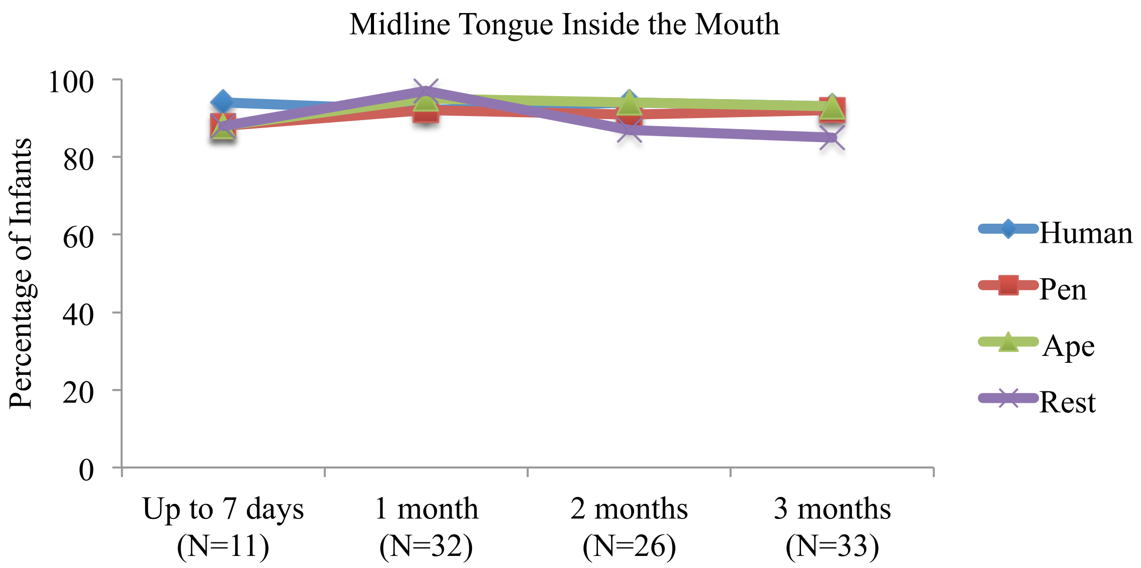

Figure 8. Percentage of infants with at least one instance of **midline tongue inside the mouth**.

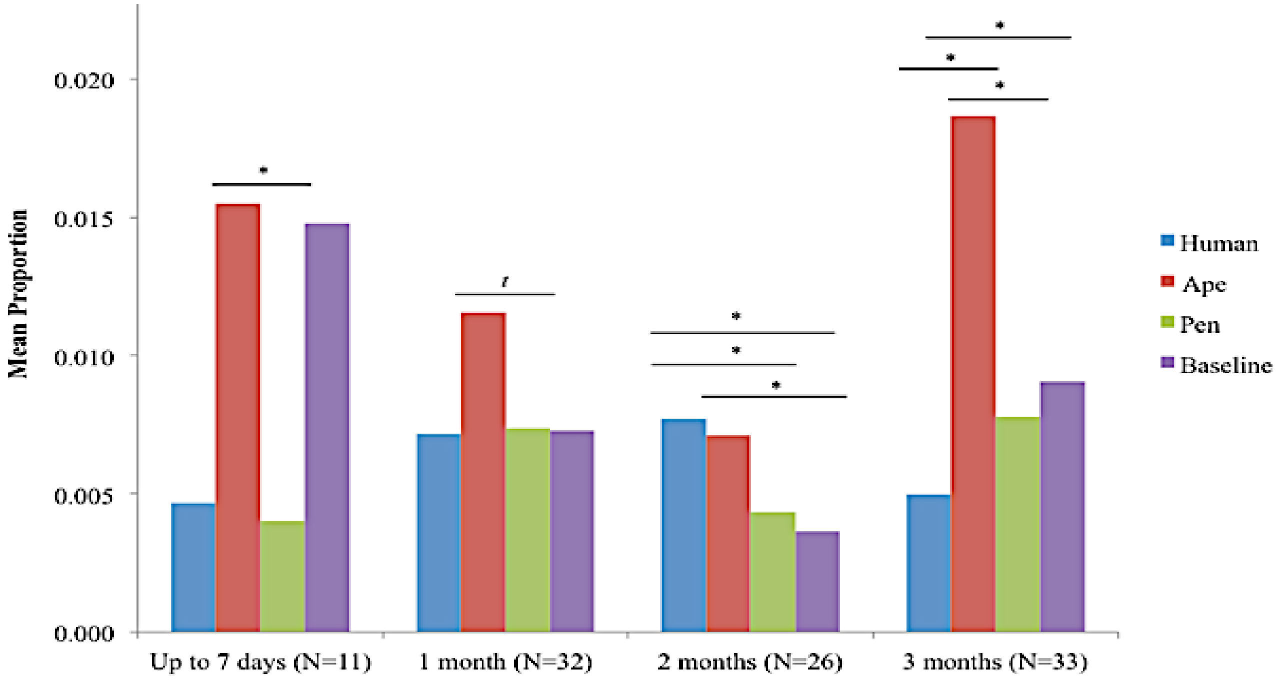

Figure 9. Mean proportion of **lateral tongue protrusions** for infants with at least one instance of lateral tongue protrusion in the human and/or the ape condition. *Note:* $*p< .05$; $^{t}p< .10$

Cross-sectional analyses. Time 1 (up to 7 days; *N*=11). The proportion of **lateral tongue protrusions** for each condition was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 2.967$, $p = .397$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of lateral tongue protrusions between the human, pen, ape and baseline condition. The results indicated that there was a higher proportion of lateral tongue protrusions in the ape condition than in the pen condition. $Z = 2.310$, $p < .021$. None of the other pairwise comparisons were statistically significant, *Zs* < 1.156, *ps* > .248.

Cross-sectional analyses. Time 2 (1 month; *N*=32). The proportion of **lateral tongue protrusions** for each condition was compared through the Friedman Test, which was only marginally significant, $X^2(3) = 6.506$, $p = .089$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of lateral tongue protrusions between the human, pen, ape and baseline condition. The results indicated that there was a higher proportion of tongue protrusions in the ape condition than in the pen condition; but this difference was only marginally significant, $Z = 1.709$, $p = .088$. None of the other pairwise comparisons were statistically significant, *Zs* < 1.610, *ps* > .107.

Cross-sectional analyses. Time 3 (2 months; *N*=26). The proportion of **lateral tongue protrusions** for each condition was compared through the Friedman Test, which was statistically significant, $X^2(3) = 11.956$, $p = .008$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue**

protrusions between the human, pen, ape and baseline condition. The results indicated that there was a higher proportion of lateral tongue protrusions in the human condition than in the pen and in the baseline condition, $Z = 3.027$, $p = .002$, and $Z = 2.501$, $p = .012$, respectively. The ape condition also had a higher proportion of lateral tongue protrusions than the baseline condition; but this difference was only marginally significant, $Z = 1.810$, $p < .070$. None of the other pairwise comparisons were statistically significant, *Zs* < 1.610, *ps* > .107.

Cross-sectional analyses. Time 4 (3 months; *N*=33). The proportion of **lateral tongue protrusions** for each condition was compared through the Friedman Test, which was statistically significant, $X^2(3) = 15.681$, $p = .001$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there were any differences in the proportion of **lateral tongue protrusions** between the human, pen, ape and baseline condition. The results indicated that there was a higher proportion of tongue protrusions in the ape condition than in human, in the pen and in the baseline condition, $Z = 3.467$, $p = .001$, $Z = 2.869$, $p = .004$, and $Z = 2.109$, $p = .035$, respectively. None of the other pairwise comparisons were statistically significant, *Zs* < 1.055, *ps* > .291.

Longitudinal analyses. Human condition (*N*=7). The proportion of **lateral tongue protrusions** for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 3.968$, $p = .265$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there was any difference in the proportion of lateral tongue protrusions between the time points. No significant result was found, *Zs* < 1.153, *ps* > .249.

Longitudinal analyses. Ape condition (*N*=7). The proportion of **lateral tongue**

protrusions for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 6.048$, $p = .109$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there was any difference in the proportion of lateral tongue protrusions between the time points. The results indicated that there was a higher proportion of tongue protrusions at times 3 (2 months) and 4 (3 months) than at time 2 (1 month), $Z = 2.201$, $p = .028$, and $Z = 1.690$, $p = .091$, respectively. No other comparison was statically significant, $Zs < 1.577$, $ps > .115$.

Longitudinal analyses. Pen condition (*N*=7). The proportion of **lateral tongue protrusions** for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = 1.340$, $p = .720$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there was any difference in the proportion of lateral tongue protrusions between the time points. No significant result was found, $Zs < 1.483$, $ps > .138$.

Longitudinal analyses. Baseline condition (*N*=7). The proportion of **lateral tongue protrusions** for each time point was compared through the Friedman Test, which was not statistically significant, $X^2(3) = .700$, $p = .873$.

Further pairwise comparisons using the Wilcoxon signed ranks test for related samples were run in order to investigate if there was any difference in the proportion of lateral tongue protrusions between the time points. No significant result was found, $Zs < 1.069$, $ps > .285$.

Discussion

In the present study, infants were longitudinally assessed (up to 7 days after birth, and at 1, 2, and 3 months of age) to investigate the development of imitative skills. In each assessment, infants were prompted with a moving pen, an ape robot protruding its tongue to the side, and an adult modelling lateral tongue protrusion. Infants' tongue movements were coded according to their direction (forward or lateral tongue protrusion), and intensity (short or long tongue protrusion). As expected, throughout the study, the proportion of the time the infants were awake during the experiment increased significantly. Despite that, I did not find any sign of imitation across conditions and time points.

Study Goals

Objective 1. This study's first goal was to replicate and to extend Meltzoff and Moore's (1994, 1989, 1983, 1977) findings on neonatal imitation. However, contrary to Meltzoff and Moore's outcomes, infants in the present study did not imitate the behaviour of lateral tongue protrusion at any time point. In fact, only a few infants produced lateral tongue protrusions throughout the experiment (see Table 8 and Figure 5), and, when they did, this behaviour was extremely rare. The absence of imitation was true even when I excluded from the analyses the infants who did not present any lateral tongue protrusion (see Figure 9). I also did not find signs of strong stability across conditions and time, i.e., different infants stuck out their tongues at different conditions and times. This lack of stability suggests that lateral tongue protrusions were random and not a systematic behaviour as claimed by Meltzoff and Moore.

A possible explanation for the discrepancy between Meltzoff and Moore's (1994, 1989, 1983, 1977) results and mine is that they used a lenient method to investigate imitation in infancy. The authors compared the frequency of infants' tongue protrusion in the tongue protrusion modelling condition against the frequency of infants' tongue protrusion in the mouth opening modelling condition. The authors' claim for imitation is based on the fact that the frequency of tongue protrusion was higher in the tongue protrusion modelling than in the mouth opening modelling conditions. Similarly, they found the frequency of mouth opening to be higher in the mouth opening modelling than in the tongue protrusion modelling condition. Conversely, when looking within the same condition, Meltzoff and Moore found the frequency of tongue protrusion to be higher than the frequency of mouth opening in both conditions (tongue protrusion versus mouth opening modelling).

In the current study, I used a different and more conservative test than Meltzoff and Moore (1994, 1989, 1983, 1977) for imitation. Firstly, I expected the infants to modify a spontaneous behaviour (forward tongue protrusion) in response to the lateral tongue modelling conditions (similarly to Meltzoff and Moore, 1994). The reasoning behind it was to separate a possible instinctive and frequent behaviour (i.e., sucking reflex leading to forward tongue protrusion), from a true imitative behaviour. Secondly, I had a pen, an ape and a baseline condition (Meltzoff and Moore's studies did not have a baseline condition); therefore, evidence for imitation would only be true if the infants had a higher proportion of lateral tongue protrusion in the human (and possibly in the ape) condition than in the other ones. None of these two requirements were satisfied, i.e., Meltzoff and Moore's results were not replicated here.

These null results are further supported by Oostenbroek et al.'s (2016) recent publication. In their longitudinal study, these researchers also did not find any sign of tongue protrusion imitation by newborns and infants. Oostenbroek and colleagues considered the infants' response to be evidence for imitation, only if the frequency of tongue protrusion in the tongue protrusion modelling condition were significantly higher than the frequency of tongue protrusion in other

10 gesture modelling conditions (e.g., box opening, index finger protrusion, etc.). The authors' requirements were not met, and they also concluded that human newborns are not able to imitate other human beings.

Comparing the proportion of lateral tongue protrusion in the current study to that of Meltzoff and Moore's (1994), I found that the proportion of such behaviour in their study is almost 10 times greater than in mine (see Table 9 below). This figure is similar to forward tongue protrusion; Meltzoff and Moore's (1994, 1989, 1983, 1977) frequency count was about 2 times greater than the proportion I reported here. In addition, Meltzoff and Moore's (1989, 1983, 1977) samples had approximately twice as many infants who produced tongue protrusion in response to tongue protrusion modelling than I had. Similar to my results, the proportion of infants' forward tongue protrusion in response to the tongue protrusion modelling condition and the percentage of infants responding with tongue protrusion to the tongue protrusion modelling condition were lower in Oostenbroek et al. (2016) than the Meltzoff and Moore's studies (see Table 9).

A possible explanation for Meltzoff and Moore's resulting proportions (as well as their positive findings for neonatal imitation) is their small and conceivably biased sample. The authors reported a large rate of attrition in their studies, ranging from 50% to 80% of the participants. They had samples composed by 6 and 16 newborns (see Table 1); their largest sample consisted of 40 infants. Both the present study and Oostenbroek et al.'s (2016) had at least a 2 times larger sample than those of Meltzoff and Moore's. Our samples are likely less biased and definitely lent us greater power to find any sign of neonatal imitation.

In conclusion, taking together the present study and Oostenbroek et al.'s (2016) study we have strong evidence to challenge Meltzoff and Moore's (1994, 1989, 1983, 1977) claim that human newborns can imitate other humans from birth. The theoretical implications of challenging the authors' claim are discussed below.

Table 9

Data from Current and Baseline Studies

Published articles	Method of comparison	Average frequency of forward TP (by 1 sec) in response to TP modelling	Percentage of infants that produced TP in a TP modelling condition
This study (*N*=90)	Target behaviour across conditions	up to 7 days = .020 1 month = .050 2 months = .030 3 months = .030	53% to 80%
Oostenbroek et al., 2016 (*N*=106)	Cross-target procedure (#TP in TP modelling condition vs. #TP in other conditions)	1-week-olds = .027 3-week-olds = .034 6-week-olds = .047 9-week-olds = .054	46.7 to 64.2%
Meltzoff & Moore, 1994 (*N*=40)	Cross-target procedure	6-week-olds = .130	80%
Meltzoff & Moore, 1989 (*N*=40)	Cross-target procedure	40-hour-olds = .028	50%
Meltzoff & Moore, 1983 (*N*=40)	Cross-target procedure	32-hour-olds = .041	65%
Meltzoff & Moore, 1977 (*N*=6–12)	Cross-target procedure	14-day-olds = .133	-

Note: The author of this dissertation calculated the frequencies and percentages presented on this table. Calculations were done from data available in the published version of the studies. TP = tongue protrusion; # = number of.

Objective 2. This study's secondary goal was to investigate if newborns are biased toward specifically imitating humans, or more broadly, face-like stimuli's gestures. Largely, I intended to test Meltzoff's (2007, 2005) *like me* equivalence hypothesis. Evidence supporting the *like me* equivalence would be found if infants produced more lateral tongue protrusion in the human condition than in the other conditions. On the other hand, evidence for the face-like stimuli hypothesis would be found if infants produced more lateral tongue protrusion in the human and in the ape condition than in the pen and in the baseline condition. I did not find evidence for either the *like me* equivalence or the face-like stimuli hypothesis. The infants in the present study did not show any preference to imitate human, or human and ape when compared to the pen and the baseline conditions. This was true even when forward and lateral tongue protrusion were added together or when infants with no instance of lateral tongue protrusion were removed from the analyses. These results are not surprising given that infants participating in this study did not show any ability of imitation; one needs to be able to imitate before any bias in this behaviour is developed.

Although my results question the existence of a bias for imitation in humans in the first 3 months of age, it could be that a preference for imitating conspecifics appears later in infancy; maybe around 8 or 9 months when infants learn to share their attention with other people and the evidence for imitations is not conflicting (e.g., Tomasello, 1999, 2003). Future studies can investigate such hypothesis by adapting the current study's methodological design to that age period. A possibility is to run a study in which a person, an ape, and a robot (or another object) perform different actions with an object to see which actions the infants would prefer to imitate and for how long.

Objective 3. This study's final objective was to investigate age-related changes in early imitation skills. Given that no evidence for imitation was found at any age, it is impossible to test for longitudinal changes. Even when I collapsed the types of tongue protrusion (lateral/forward), I still did not find any consistent pattern of tongue protrusions across time (see Figure 4).

For instance, when I added together forward and lateral tongue protrusions, at time 1 (up to 7 days), I found a higher proportion of tongue protrusion in the baseline condition than in the other conditions; at time 2 (1 month) I found the baseline and the human condition to have a higher proportion of tongue protrusion than the ape and the pen conditions. I found no significant result at time 3 (2 months), but at time 4 (3 months), the ape condition had a higher proportion of tongue protrusion than the human and the pen condition (see Figure 4).

When I analyzed lateral tongue protrusion only for infants with at least one instance of that behaviour I found a trend for a higher proportion of lateral tongue protrusion in the ape condition than in the other conditions (see Figure 9). However, this pattern disappeared at time 3 (2 months) and was only marginally significant at time 2 (1 month).

In conclusion, the present study challenges the existence of neonatal imitation in humans as well as the *like me* equivalence as a valid framework to explain early imitation and its connection to later social cognitive skills as discussed in the introduction.

Implications for the *Like Me* Framework

According to Meltzoff (2007, 2005), it is through early imitation that infants develop the sense that they are *like* other human beings. The *like me* equivalence is then established through an action-perception supramodal representation system. Relying on such representation, the author claims that through a first-person perspective, infants are able to connect their own mental states to others'. The problematic inference of Meltzoff's theory is that more sophisticated forms of social cognition, e.g., theory of mind, would depend on an innate ability to imitate (Gopnik &

Meltzoff, 1994; Meltzoff & Gopnik, 1993; Meltzoff, 2005, 2007; Trevarthen & Aitken, 2001). Unfortunately, social cognitive theories started to take neonatal imitation as a basic and necessary assumption to build from (Heyes, 2016; Ray & Heyes, 2011, Oostenbroek et al., 2016, 2013), a context that does not foster further investigations of neonatal imitation (Heyes, 2016).

In the current study, I presented strong evidence that newborns, and even 1-, 2-, and 3-month old infants, do not imitate other human beings. I also discussed further evidence presented by Oostenbroek et al. (2016). Only a few studies have previously called neonatal imitation into question (e.g., Anisfeld, 2001, 2005; Jacobson, 1979; and Jones, 1996). If humans are not born with imitative abilities, we then need to explain how imitation develops in infancy.

Alternative frameworks are the associative sequence learning model proposed by Ray and Heyes as well as the recent model proposed by Jones'(2016, 2017). As discussed before, Jones' model is based on a reformulation of Piaget's (1962, 1953) theory of imitation and assumes that humans learn to imitate through their social interactions (see also Catmur, Walsh, & Heyes, 2009). Similarly, Ray and Heyes also move from Meltzoff's (2007, 2005, 1999) idea of infants projecting their mental states into other people to the idea that infants learn to imitate through their social interactions. In support of the associative sequence and Jones' models, there is evidence in the literature that learning associative skills at 1 month predicts infants' imitative skills at 9 months (Reeb-Sutherland et al., 2012).

Although the current study does not provide direct evidence for Ray and Heyes' (2011) or Jones' (2015, 2016) theories, their models would explain why I did not find any sign of imitation in my sample. While imitation would take time to develop and require a developmental environment that offers learning experiences, the current study only investigated infants up to 3 months of age. According to Piaget (1962, 1953), true imitative behaviours do not appear until infants start to combine schemes (~ 8 months; see also Jones, 2009, 2012, 2016). Taking that into account, future studies could follow up infants in the first year of life in order to test Jones' proposal and the associative sequence learning model. Infants can be assigned to groups where parents are encouraged to imitate their children, to put mirrors in infants' preferred room, or even to praise infants when imitating by chance. If Jones' reformulation of Piaget's theory, or Ray and Heyes' model is correct, in all these cases we should see a faster development of imitation abilities (but not necessarily an earlier onset according to Jones's model). Evidence supporting this hypothesis comes from Jacobson's (1979; see also Anisfeld, 2005, for a discussion) study. The author assigned 12 6-month old infants to an intervention group and another 12 6-month old infants to a control group. While the former was exposed to tongue protrusion modelling daily, the later was not. At 14 week of age, infants in the experimental group tended to produce more tongue protrusions when seeing a person modelling that behaviour than when seeing a pen moving towards them. Infants in the control group did not respond selectively. Similar results were also presented by Jones (2007, 2009, 2012) and Kennedy-Constantini**,** Nielsen, and Slaughter (2015).

Implications for the Releasing Mechanism Proposal

Jacobson (1979) proposed that newborns' actions are elicited by the movements they see, and not by an attempt to match adults' behaviours. In addition, other authors have found that newborns match only tongue protrusion (Anisfeld, 2001, 1996, 1991; Abravanel & Sigafoos, 1984), which could mean that seeing a tongue protrusion or an object moving forward activates newborns' sucking reflex. The present study did not find any evidence to support Jacobson's theory.

If Jacobson's proposal was correct, infants would present a high proportion of tongue protrusion (lateral plus forward) in the human, ape and pen conditions, but not in the baseline condition. Although I did not find consistent differences between the three experimental conditions in the current study, in at least 3-time points the baseline condition had higher or similar proportions of tongue protrusion than the other conditions (see Figure 4).

The releasing mechanism proposal also predicts longitudinal differences in infants' proportion of tongue protrusion in response to stimuli. Specifically, under this proposal infants' would be expected to decrease their rate of tongue protrusion across time; similarly to what happens to other innate reflexes (Heimann, 1989, 1998; Heiman, Nelson, & Shaller, 1989; Kugiumutzakis, 1999, Maratos, 1982). Once again, the current study did not find any evidence for a significant and consistent decline in infants' proportion of tongue protrusion across time.

Lastly, if tongue protrusion was an innate reflex released by a specific stimulus, we would see a tongue protrusion response in all the newborns that participated in this study, but that was not the case (at least 18 infants at each time point had no instance of tongue protrusion; see Table 8). In conclusion, the present study challenges the releasing mechanism proposal as a valid framework to explain newborns' matching behaviours.

Implications for the Arousal and Pre-Reaching Behaviour Proposal

Jones (2017, 2007, 2006, 1996; see also Anisfeld, 2005) argues that infants produce tongue protrusion when their interest is aroused. According to the author, tongue protrusion is a pre-reaching exploratory behaviour, reflecting infants' motivation to explore and engage in something. If Jones's argument was correct, infants would show a higher proportion of tongue protrusion in the ape (unfamiliar and complex stimuli) and in the human condition (familiar but complex stimuli), than in the pen (simple stimuli) or the baseline condition (no stimuli). In the current study, I found partial support for the Jones' proposal.

At birth, infants did not present a higher proportion of tongue protrusion in the ape and/or in the human conditions than in the pen and the baseline conditions (see Figure 4). Evidence for the arousal and pre-reaching proposal showed up at time 2 (1 month; see Figures 7 and 9), at time 3 (2 months; see Figure 7) and at time 4 (3 months; see Figures 4 and 9, and the main analyses) depending on the dependent variable analysed. At these time points, we found either a significantly higher proportion of tongue protrusion in the ape and/or human condition than in all the other conditions or a higher percentage of infants with at least one instance of tongue protrusion.

However, being more conservative and analysing only the overall proportion of tongue protrusion (see Figure 4), evidence for the arousal and pre-reaching proposal is found only at time 4 (3 months). A possible explanation for this finding is that, in contrast to the other stimuli, the ape robot became an interesting stimulus to infants only around 3 months of age. It is known that despite the preference for face-like stimuli, neonates do not show any preference towards faces of their own species when given the option of also looking at a non-human primate (Di Giorgio et al., 2012, Kelly et al., 2005, Pascalis et al., 2002; Sanefuji et al., 2014). It is only around the third month of age that infants start to show a preference in looking at humans over other primates, which might be explained by a more intense exposure to humans than to primates in general (Di Giorgio et al., 2012; Sanefuji et al., 2014). Thus, it could be that around 3 months of age, infants started to find the ape robot more unusual and wanted to engage with it, to explore it. In one of Jones's (1996) study, infants' age ranged from 3 to 30 weeks of age, however, she reports data for only two infants, making it difficult to directly compare her results and mine.

Future studies should investigate further the relationship between tongue protrusions and arousal/exploratory behaviours both within and beyond the time frame of the current study.

Infants can be assigned to a condition in which parents are encouraged to show the infants an ape robot on a daily basis; in another condition, parents could be asked to avoid showing apes to their infants in general. If Jones' (1996) proposal is correct, infants that had more exposure to the ape robot should present a lower proportion of tongue protrusion when seeing a different ape robot protruding its tongue than the infants that had less or no exposure to apes.

Limitations and Future Studies

Previous studies on neonatal imitation have not discussed their coding process in depth; nonetheless, they report good inter-rater reliability. In the current study, I faced several challenges regarding reliability. Research assistants were trained over 4 months to code the participants' behaviours. I had an extra set of data we could train on, and we met weekly to code some of the videos together. We also coded separately and compared our results afterwards. Even with all this effort, we did not achieve high-reliability scores as other researchers did. Although we followed Metlzoff and Moore's (1994, 1989, 1983, 1977) instructions, as well as Oostenbroek et al.'s (2016), there is a chance that each of us used a slightly different process. In any case, there is no reason to believe this is the reason I did not replicate Meltzoff and Moore's results; I found similar proportions of tongue protrusion and infants performing tongue protrusion that Oostenbroek et al. did and neither of us found signs of imitation in neonates.

A limitation of the current study is that I could not assess newborns in a controlled laboratory environment. The experimenters went to participants' houses in order to collect the data, which resulted in different infants being assessed in different environments and different positions (see method section). While the experimenters did not have much control over nuisance variability when collecting data in such spaces, the current study certainly had ecological validity. The situations in which newborns and infants were tested are closer to daily life experiences than a controlled experimental setting. Besides, if Meltzoff's (2007, 2005, 1999; see also Meltzoff & Gopnik, 1993, and Gopnik & Meltzoff, 1994 for this discussion) claim that neonatal imitation is the key ability underpinning human socio-cognitive development was correct, such behaviour certainly would not be triggered only in a very controlled and artificial environment.

In moving forward, it may be valuable to revisit Piaget's theory (1953, 1962). According to Piaget (1953, 1962), the first imitative events in an infant's life encompass behaviours that the infant does spontaneously and repeats in circular reactions, as well as behaviours that produce sounds or any observable outcome. It is not before the coordination of secondary schemes (~ 8 to 12 months of age) that infants show signs of true imitation, first of novel movements that produce visual feedback, and later of unseen movements, such as facial expressions. To test the developmental trajectory proposed by Piaget, a longitudinal study should be carried on throughout infancy, or at least throughout the first year of age. If his proposal is correct, we will see imitation of novel transparent actions (i.e., actions that infants can see while imitating) emerging prior to imitation of novel opaque actions (i.e., facial gestures and expressions). Evidence supporting this developmental framework is found in Anisfled's (2005) and Jones' (2007, 2009, 2012, 2016) studies.

Contrary to Piaget's focus on the development of mental representations to explain opaque imitation, the associative sequence learning model (Ray and Heyes, 2011; see also Jones, 2015, 2016) explains these changes in imitative skills as a result of infants' social interactions and the consequent juxtapositions (i.e., associations) of visual behaviour/stimuli with infants' proprioceptive feedback fostered in these moments. As already suggested above, while testing the Piagetian sequence, it would also be interesting to investigate how and which types of social interactions (e.g., being imitated) might scaffold the development of imitation in infancy (see Kennedy et al., 2015).

Conclusion

The current study was the first to compare ape vs. human vs. object and to try to directly test the *like me* equivalence framework. I questioned this framework by challenging the claim of neonatal imitation and arguing that the associative sequence model or Jones' (2015, 2016) revision of Piaget's (1953, 1962) theory might be a way to predict the emergence of imitation in infancy.

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Appendix A: Descriptive Statistics for Data Screening

Table 10

Descriptive Statistics at Time 1 (*M*= 3.67 days of age; *SD*=1.38 days) for Data Screening

	Human			Pen			Ape			Baseline		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Duration (minutes)	3.53 (1.45)	1.00	8.45	3.11 (.92)	1.00	6.07	3.36 (0.93)	1.12	6.07	2.20 (.47)	1.30	3.37
Infants' State (proportion of time)												
Sleep	.21 (.19)	.00	.94	.23 (.23)	.00	.91	.22 (.20)	.00	.76	.31 (.27)	.00	.99
Drowsy	.53 (.21)	.00	.93	.51 (.25)	.04	.99	.50 (.21)	.12	.96	.42 (.26)	.00	.98
Awake	.17 (.21)	.00	.77	.16 (.20)	.00	.71	.19 (.21)	.00	.84	.11 (.16)	.00	.56
Aroused/ Crying	.09 (.13)	.00	.64	.10 (.15)	.00	.60	.10 (.14)	.00	.61	.17 (.22)	.00	.84
Frequency of Forward Tongue Protrusion												
Inside	17.96 (31.93)	.00	216.00	13.29 (14.07)	.00	71.00	12.47 (15.71)	.00	85.00	15.80 (18.95)	.00	81.00
Short	3.18 (5.60)	.00	27.00	3.24 (5.73)	.00	22.00	3.02 (4.36)	.00	19.00	4.24 (6.62)	.00	26.00
Long	.35 (1.51)	.00	10.00	.24 (.84)	.00	5.00	.49 (1.60)	.00	9.00	.24 (1.03)	.00	7.00
Frequency of Tongue Lateral Tongue Protrusion – Right Side												
Inside	.16 (.54)	.00	3.00	.16 (.50)	.00	2.00	.14 (.49)	.00	3.00	.18 (.48)	.00	2.00
Short	.08 (.34)	.00	2.00	.04 (.20)	.00	1.00	.20 (.80)	.00	5.00	.12 (.48)	.00	3.00
Long	.00 (.00)	.00	0.00	.00 (.00)	.00	.00	.00 (.00)	.00	.00	.00 (.00)	.00	.00
Frequency of Lateral Tongue Protrusion – Left Side												
Inside	.29 (.76)	.00	4.00	.18 (.52)	.00	2.00	.33 (1.21)	.00	6.00	.18 (.52)	.00	3.00
Short	.12 (.33)	.00	1.00	.20 (.72)	.00	4.00	.31 (1.45)	.00	10.00	.29 (1.45)	.00	10.00
Long	.00 (.00)	.00	.00	.02 (.14)	.00	1.00	.06 (.31)	.00	2.00	.06 (.31)	.00	2.00

N= 51 (Male= 24; Female = 27)

Table 11

Descriptive Statistics at Time 2 (*M*= 30.57 days od age; *SD*= 3.01 days) for Data Screening

	Human			Pen			Ape			Baseline		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Duration (minutes)	3.75 (1.64)	1.00	9.57	3.46 (1.03)	1.72	7.42	3.72 (1.40)	1.57	9.22	2.27 (.59)	1.05	4.37
Infants' State (proportion of time)												
Sleep	.06 (.10)	.00	.39	.08 (.13)	.00	.65	.09 (.14)	.00	.73	.10 (.20)	.00	1.00
Drowsy	.36 (.22)	.00	.88	.36 (.23)	.02	.94	.35 (.24)	.01	.92	.31 (.25)	.00	.90
Awake	.43 (.29)	.00	.96	.46 (.36)	.00	1.00	.43 (.28)	.00	.97	.48 (.34)	.00	.99
Aroused/ Crying	.14 (.17)	.00	.93	.12 (.15)	.00	.74	.13 (.15)	.00	.59	.10 (.13)	.00	.58
Frequency of Forward Tongue Protrusion												
Inside	21.73 (23.14)	.00	128.00	20.99 (23.74)	.00	137.00	23.76 (24.58)	.00	133.00	12.82 (12.41)	.00	47.00
Short	8.76 (13.68)	.00	65.00	6.70 (11.50)	.00	67.00	6.64 (9.15)	.00	42.00	5.47 (9.94)	.00	55.00
Long	1.03 (2.33)	.00	14.00	.55 (1.80)	.00	14.00	.73 (1.87)	.00	13.00	.38 (.87)	.00	5.00
Frequency of Tongue Lateral Tongue Protrusion – Right Side												
Inside	.23 (.90)	.00	7.00	.20 (.57)	.00	3.00	.31 (.76)	.00	4.00	.22 (.58)	.00	3.00
Short	.23 (.71)	.00	5.00	.30 (.90)	.00	6.00	.27 (.90)	.00	6.00	.14 (.45)	.00	3.00
Long	.05 (.28)	.00	2.00	.01 (.12)	.00	1.00	.00 (.00)	.00	.00	.01 (.12)	.00	1.00
Frequency of Lateral Tongue Protrusion – Left Side												
Inside	.34 (.85)	.00	4.00	.28 (.79)	.00	4.00	.42 (1.12)	.00	7.00	.18 (.60)	.00	3.00
Short	.30 (.84)	.00	5.00	.34 (.94)	.00	4.00	.55 (1.30)	.00	7.00	.26 (.97)	.00	6.00
Long	.04 (.20)	.00	1.00	.05 (.28)	.00	2.00	.05 (.23)	.00	1.00	.03 (.16)	.00	1.00

N= 74 (Male= 30; Female= 44)

Table 12

Descriptive Statistics at Time 3 (*M*= 61.13 days of age; *SD*= 3.88 days) for Data Screening

	Human			Pen			Ape			Baseline		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Duration (minutes)	4.13 (1.01)	2.18	8.02	3.57 (.54)	1.68	5.62	3.76 (.71)	1.83	5.78	2.37 (.68)	1.68	4.80
Infants' State (proportion of time)												
Sleep	.04 (.12)	.00	.77	.03 (.08)	.00	.58	.03 (.07)	.00	.46	.04 (.10)	.00	.69
Drowsy	.26 (.23)	.00	.96	.26 (.25)	.00	.97	.26 (.23)	.00	.91	.28 (.24)	.00	1.00
Awake	.62 (.29)	.00	1.00	.66 (.28)	.01	.99	.63 (.28)	.02	.99	.63 (.29)	.00	1.00
Aroused/ Crying	.08 (.16)	.00	.98	.04 (.08)	.00	.51	.08 (.10)	.00	.44	.05 (.08)	.00	.48
Frequency of Forward Tongue Protrusion												
Inside	19.54 (20.38)	.00	95.00	12.47 (16.25)	.00	101.00	18.95 (17.32)	.00	90.00	9.20 (13.43)	.00	71.00
Short	6.78 (11.05)	.00	62.00	4.58 (7.44)	.00	45.00	4.61 (8.58)	.00	40.00	3.53 (5.54)	.00	35.00
Long	.41 (.97)	.00	4.00	.42 (1.32)	.00	7.00	.27 (1.01)	.00	7.00	.43 (1.68)	.00	14.00
Frequency of Lateral Tongue Protrusion – Right Side												
Inside	.15 (.48)	.00	3.00	.14 (.59)	.00	4.00	.18 (.50)	.00	3.00	.11 (.39)	.00	2.00
Short	.24 (.71)	.00	5.00	.20 (.72)	.00	5.00	.19 (.66)	.00	4.00	.16 (.61)	.00	4.00
Long	.18 (1.08)	.00	9.00	.03 (.23)	.00	2.00	.03 (.16)	.00	1.00	.01 (.11)	.00	1.00
Frequency of Lateral Tongue Protrusion – Left Side												
Inside	.19 (.58)	.00	3.00	.18 (.66)	.00	5.00	.23 (.75)	.00	4.00	.15 (.43)	.00	2.00
Short	.28 (.93)	.00	7.00	.16 (.56)	.00	3.00	.23 (.75)	.00	4.00	.06 (.29)	.00	2.00
Long	.01 (.11)	.00	1.00	.01 (.11)	.00	1.00	.09 (.68)	.00	6.00	.03 (.16)	.00	1.00

N= 79 (Male= 37; Female= 42)

Table 13

Descriptive Statistics at Time 4 (*M*= 90.02 days od age; *SD*= 3.03 days) for Data Screening

	Human			Pen			Ape			Baseline		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Duration (minutes)	3.93 (1.14)	2.00	8.45	3.50 (.48)	2.02	4.32	3.80 (1.01)	2.05	8.98	2.18 (.53)	1.00	4.10
Infants' State (proportion of time)												
Sleep	.03 (.11)	.00	.98	.01 (.02)	.00	.09	.01 (.02)	.00	.08	.01 (.02)	.00	.15
Drowsy	.28 (.25)	.00	.95	.24 (.24)	.00	.97	.17 (.17)	.00	.93	.18 (.20)	.00	.99
Awake	.63 (.28)	.00	1.00	.71 (.25)	.03	1.00	.76 (.20)	.01	.99	.77 (.22)	.00	1.00
Aroused/ Crying	.06 (.13)	.00	.85	.04 (.09)	.00	.60	.06 (.11)	.00	.54	.03 (.11)	.00	.80
Frequency of Forward Tongue Protrusion												
Inside	20.16 (23.48)	.00	117.00	12.65 (16.40)	.00	78.00	19.53 (22.40)	.00	122.00	10.18 (15.62)	.00	83.00
Short	5.39 (8.15)	.00	.48	3.47 (5.31)	.00	23.00	7.82 (15.58)	.00	83.00	3.48 (6.25)	.00	37.00
Long	.39 (1.08)	.00	8.00	.33 (1.37)	.00	12.00	.55 (1.79)	.00	14.00	.24 (.86)	.00	6.00
Frequency of Lateral Tongue Protrusion – Right Side												
Inside	.09 (.33)	.00	2.00	.09 (.33)	.00	2.00	.26 (.66)	.00	4.00	.04 (.19)	.00	1.00
Short	.15 (.59)	.00	4.00	.16 (.81)	.00	7.00	.14 (.44)	.00	2.00	.12 (.45)	.00	3.00
Long	.02 (.22)	.00	2.00	.00 (.00)	.00	.00	.02 (.15)	.00	1.00	.01 (.11)	.00	1.00
Frequency of Lateral Tongue Protrusion – Left Side												
Inside	.31 (1.34)	.00	11.00	.11 (.38)	.00	2.00	.33 (1.27)	.00	8.00	.17 (.49)	.00	2.00
Short	.21 (.85)	.00	7.00	.25 (.67)	.00	4.00	.38 (1.17)	.00	9.00	.21 (.79)	.00	6.00
Long	.05 (.43)	.00	4.00	.00 (.00)	.00	.00	.00 (.00)	.00	.00	.00 (.00)	.00	.00

N= 85 (Male= 39; Female= 46)