Title: Unravelling factors of faithful imitation throughout childhood

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Research Degree in Psychology

Date of Submission: August 2017

Word count (excl. References): 60558 words

ABSTRACT:

The following thesis examines factors that affect children's imitation, and presents evidence that imitation is a composite ability which involves multiple mechanisms developing throughout childhood. In Chapter 1 previous findings are reviewed to highlight the mechanisms underlying the ability to reproduce other people's actions. The evidence suggests that imitation, whilst based on basic action control mechanisms in infancy, is also affected by higher-order cognitive processes in later childhood. Previous literature is still unclear on how the influence of such processes changes at different ages. Chapter 2 used a successive-models task with children aged 2 to 12 years to reveal how children's imitation changes with age. Results showed that whilst children under the age of 5 years did not imitate deviant models as much as the first model, children above the age of 6 years begin to copy multiple models faithfully, particularly after the age of 10 years. Chapter 3 investigated the role of multiple factors that may have made children under the age of 5 years imitate deviant models less than the original model. In particular, it was found that model evaluations, object associations, and motor inhibitory skills all affect children's imitation of multiple models. These findings support the interpretation that imitation requires different abilities depending on the type of action that is being imitated. Chapter 4 shows that children's imitation also depends on the type of goal that they associate with the action. By pre-school age children will imitate actions faithfully if they believe that the goal of the action was the movement itself. The results of the thesis support the idea that imitation, while involving general processes of action control, is also affected in a top-down manner by higher-order cognitive abilities after infancy.

285 words.

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ACKNOWLEDGEMENTS:

I would like to thank a number of people for helping me to write this thesis. First and foremost, my thanks goes to my main supervisor, Dr Eva Rafetseder. Her expertise, boundless enthusiasm, critical rigour and passion for developmental psychology have made it her a joy to work with over these last three years. I am incredibly indebted to her, and immensely grateful. I would also like to thank Professor Christine Caldwell and Dr Martin Doherty whose assistance as secondary supervisors has been very much appreciated. The role of secondary supervisor can be challenging, and yet I always felt supported and encouraged by their feedback and suggestions. I thank Rosie Gillespie, Brier Rigby Dames, Grace Schofield, Caragh o'Brien, Nicole Wilson, Zoe Loach, Georgia Alexandrou, Bethany Black, Megan Everts, Papoula Romao and Naomi St Martin for their assistance in data collection – their enthusiasm and passion for working with children made working on these studies much more enjoyable. I would also like to thank Jim Anderson for his helpful suggestions with regards to data interpretation. I thank the children, staff and parents who assisted me with my work at the different nurseries across Scotland. Finally, my thanks goes to my parents, and my wife, Lindsay. Their unwavering support helped me get through the difficult parts of this process and made me enjoy the good parts all the more.

CHAPTER 1

1. Introduction:

Understanding how children learn to copy other people and the factors that determine what they copy has been the focus of a considerable amount of research for decades. Imitation is a foundational ability in human development – it helps foster relationships with other people (Chartrand & Bargh, 1999; Lakin & Chartrand, 2003), acquire cultural and tool-related knowledge as an alternative to trial-and-error learning (Gardiner, Bjorklund, Greif & Gray, 2012; Gardiner, 2014) and allows people to gain knowledge already existing in their social group (Schillaci & Kelemen 2014). This thesis will provide an investigation of imitation throughout childhood. It will focus on cognitive processes known to develop during childhood and will examine whether these processes affect children's imitation. It will also analyse the role of goal understanding in imitative behaviour. An action's goal will be defined as a perceived external outcome, an external state of the world brought about by that action (Csibra & Gergely, 2007; Perner & Doherty, 2005). The thesis will thus provide a comprehensive analysis what drives copying behaviour at different ages.

There are varying definitions of what constitutes imitation, each with slightly different implications. It has been defined as "the recognition and reproduction of the goal of an observed behaviour, as well as the specific actions that brought about that goal" (Want & Harris, 2002, p. 3; see also Tomasello, 1990). According to this definition an understanding of the goal of an action is required in order to be imitating: one must realise that the model held a goal in mind and that their actions were directed specifically for achieving that goal. Want and Harris (2002) point out that it is possible for the learner to be unaware as to how actions achieve the model's goal – this ignorance as to the specific effects of the actions towards the goal is what distinguishes "blind imitation" from "insightful imitation". Other definitions have limited imitation to be copying the actions of another (Whiten, McGuigan, Marshall-Pescini & Hopper, 2009) in contrast to emulation, where one deviates from imitating the precise actions observed. This view does not specify whether the learner requires an understanding of the model's goals, although Want and Harris refer to imitation without an understanding of the model's goal as "mimicry".

An important caveat should be addressed at this point: the term "goal" has been used with varying definitions. Some authors have equated "goal" with "a desire to bring about an external state of the world" (Tomasello, Carpenter, Call, Behne & Moll, 2005). But this does not differentiate between goals (as external states of the world) and intentions (which are mental states, and involve a desire to bring about an external state of the world). Perner and Doherty (2005) highlight that actions can be understood as *goal-oriented* (i.e., an action is done to bring about an effect in the world) without understanding that the model was acting with the intention to bring that goal about. The latter case is referred to as *goal-directed* action, when one understands that the action was performed by the model with a particular goal in mind (i.e., an intention). This is made particularly clear when considering failed intentions and unexpected outcomes, as outlined in the following example:

> *Picture James Bond who has infiltrated the villainous lair of the evil Dr. Wunderkind. Bond only has his trusty gadgets with which to foil the mad doctor's dastardly plan to destroy the world. He creeps into a room and sees Wunderkind sitting at his Doomsday machine. To stop him from destroying the world, Bond decides to shoot a sleeper dart from his watch towards Wunderkind. Bond now has an intention – it involves incapacitating Wunderkind (the outcome) by shooting him with a sleeper dart (the action). He takes aim, and fires – but oh no! He misses and the dart shoots past Wunderkind, hitting a button on his desk. It's the trapdoor to the pool full of sharks… Wunderkind falls down the hole with a final, defiant scream and the world is saved.*

In this example, the outcome Bond wanted was satisfied, but not in the way he planned. His intention was to incapacitate Wunderkind using the dart: this outcome was achieved but only by using a different method. Thus his intention was not satisfied. Whilst Bond may have meant the achieved outcome of incapacitating Dr Wunderkind, he did not mean to do so by dropping him into the shark tank. There is a difference between understanding an action as bringing about a goal and understanding that the model was using that action with a particular goal in mind. Using Perner and Doherty's terminology, a goal-oriented understanding would not allow us to understand why Bond would be disappointed at his marksmanship: only when we grasp his action as goal-directed do we understand why he would be annoyed that he was unable to hit Wunderkind, even though he incapacitated him via shark instead.

Following previous distinctions, I will use the term "mimicry" to refer to copying another's actions without understanding that those actions were done to achieve a goal. The term "imitation" will be used to refer to copying another person's actions and understanding that those actions have a goal, but only in the sense of goal-oriented action as defined by Perner and Doherty (2005). As will be seen below, there is conflicting evidence over whether intentions are understood in infancy, therefore relating imitation to goal-oriented action avoids involving intentional understanding. It will also permit the distinction between cases when children understand the goals of actions and when they merely reproduce those actions blindly (which will be termed mimicry). Having clarified this terminology, the first step is to examine the beginnings of social learning, and analyse the way infants begin to copy other people.

2. Infancy: imitation or mimicry?

Is imitation special? Evidence for goals and intentions in infancy

Different theories have been proposed over whether infants' imitation can be considered mimicry or imitation. One of the earlier theories was formulated from the seminal work performed by Meltzoff and colleagues (Meltzoff & Moore, 1977, 1983; Meltzoff, 1995). Meltzoff's work on imitation in neonatal infants and young children raised critical questions about the nature of imitation and the way this ability develops throughout childhood. They argued for a nativist approach to social cognition, positing that children show an innate capacity and tendency for imitation. They also suggested that children develop an understanding of goals and intentions within the first two years of life and that this subsequently guides their imitation. These conclusions came from several studies: Meltzoff and Moore (1977) observed that new-borns (under one month of age) would imitate facial movements demonstrated to them by adults – they replicated this finding with babies less than 71 hours old (Meltzoff & Moore, 1983). Meltzoff subsequently argued that children show an innate proclivity to copy the actions of others, though he does specify that development helps this tendency improve throughout childhood (Meltzoff, 1995). In the same paper Meltzoff (1995) conducted studies on children's understanding of failed intentions. 18-month-olds observed a model attempt an action (e.g. pull a dumbbell apart) but fail, and were then given the opportunity to act on the same materials as the model. Eighteen-months-olds would not simply repeat the actions they saw the model do, but would perform the full attempted action – they would pull the dumbbell apart instead of merely tugging on the ends as the model had done. This effect only occurred when the model was a person but not when children observed a set of mechanical arms attempt the same actions. Meltzoff deduced that children at 18 months reason about actions in terms of intentions: if they were focussing merely on reproducing an end goal then they would not have differentiated between mechanical and human models. Thus, Meltzoff argued that infants not only imitated using a goal-oriented understanding of actions, they also understand actions as goal-directed. Given the finding of neonatal imitation and completion of failed acts, Meltzoff concluded that infants use intention-reading from very early on in their development and that imitative abilities are already quite complex within the first two years of life. This account was formally described in the active-intermodal mapping model of imitation (the AIM model) formulated by Meltzoff and Moore (1997).

Whilst Meltzoff's account helps explain children's strong proclivity to imitate, others have argued that this theory is not the correct way of interpreting the data. Alternative explanations have been proposed for the findings of both neonatal imitation and replication of failed outcomes. For instance Meltzoff and Moore's finding of neonatal imitation (1977) has not been consistently replicated. Oostenbroek et al. (2016) conducted a longitudinal study with infants from 1 week to 9 weeks of age, and did not find reliable imitation of various movements at any stage. Similarly, the only gesture consistently found to be imitated by neonates across multiple studies is tongue protrusion (Anisfield, 1996; Ray & Heyes, 2011). However infants have also been shown to stick out their tongue in response to other stimuli such as a felt pen tip moving close to and then away from the infants' face (Ray & Heyes, 2011). These authors suggest that sticking out one's tongue may be an excitatory response to stimuli resembling an approaching nipple. Given that the response is reliably elicited by other stimuli, not just the same movement, this behaviour cannot be taken as evidence of imitation or mimicry (as both imply a one-to-one matching between stimulus and response). As such this weakens the case for the existence of neonatal imitation.

With regards to ascribing intentions to failed actions, alternative ways of interpreting the data have been suggested. Ruffman, Taumoepeau and Perkins (2012) proposed that children's completion of failed actions can be explained by action outcome reasoning, not mental state understanding. When children see the model attempt an action, they may predict that the action involved will lead to a likely end state (e.g. pulling a dumbbell's ends = the dumbbell will come apart). By 18 months infants have experience of seeing others pull on things and know that manipulating objects has effects – the primary learning context for children during the second and third years of life is mainly through object-led activities with adults (Whitebread & O'Sullivan, 2011). Infants' joint attention between objects and people in play settings increases between the ages of 6 and 18 months (Bakeman & Adamson, 1984), meaning that during their second year infants are used to seeing adults manipulate objects. Infants could thus reason about likely outcomes (or goals, in the goal-oriented sense) from observing other people's actions. Their ability to predict action outcomes is related to their own action experience (Hunnius & Bekkering, 2014): given that children typically have much less experience observing machines pull objects, it may have been harder for them to infer the goal "pull the dumbbell apart" from the machine model. As such it is not necessary to posit that infants understand intentions to explain their completion of failed actions: they can infer the goal of a failed action from their own action experience and are primed to perform the goal they have associated with those actions. If infants reason about goals at all to imitate, it is goals in the sense of goal-oriented action (this action Y will achieve effect X) and not as goal-directed action (the model intends to bring about effect X by using this action Y). In conclusion Meltzoff's account, whilst able to explain some of the findings, is less parsimonious and less well supported than other accounts in the literature (as we shall see below).

The principle of rational action

A different account of imitation in infancy was proposed by Gergely and Csibra (2003). According to their account infants use a “principle of rational action” to evaluate the behaviours of those around them. To illustrate consider an example provided by the authors themselves (Gergely & Csibra, 2006). A woman named Sylvia recalls that, whenever her mother would prepare a roast joint, she would always cut off the ends before placing it in the oven. Therefore every time Sylvia would prepare a roast she cut each end off before placing it in her own oven. As a grown woman, Sylvia has her mother round for lunch and decides to prepare a roast. While she is preparing it and cuts the ends off, her mother enters and asks her why she is cutting the ends off. Confused Sylvia replies “Well, that’s how you always did it.” Her mother replies “Well, that’s because my oven was too small!”

In the example above Sylvia assumed that her mother had a good reason for cutting the ends off of the roast before placing it in the oven. As it turns out she did, as her oven was too small, but Sylvia did not know the reason and subsequently assumed that it should apply to herself as well. The principle of rational action can thus be formulated as *agents have a good reason for performing the actions they* do. If I see someone show me an action, I assume that they had a good reason for doing the action in the way they did. The principle of rational action posits that during the first year of life, infants’ understanding of actions is teleological: they will believe that actions will be done to achieve a goal, and this action will be done because of certain constraints of the situation (Gergely & Csibra, 2003). Infants can evaluate whether the context permits certain actions, and whether an action is an efficient way of achieving a specific goal. The authors highlight that this does not require understanding intentions or theory of mind, but merely relies on reasoning about likely goals from the context. If Sylvia sees her mother cut off the ends of the roast, she will assume this is done for the goal of cooking the roast. She does not need to understand intentions, as in that her mother’s actions are done with a particular goal in mind, and she intends certain consequences will occur because of her actions.

Evidence for children using the principle of rational action comes from studies looking at how children imitate models doing things in unexpected ways. For example Gergely, Bekkering and Király (2002) conducted a study with 14-month-olds who observed a model turn on a lamp using her head to push the switch. In one condition the model had a blanket wrapped around her and was holding it with her hands appearing to be cold; in the other condition the model’s hands were free and placed on the table on either side of the lamp. The infants used their own heads to turn on the lamp significantly more in the hands-free condition than in the blanket condition. The authors argued that the infants assumed that the model had a good reason for not using her hands in the hands-free condition, making them copy the head touch more.

Schwier, Van Maanen, Carpenter and Tomasello (2006) found a similar result with 12-month-olds. In their study infants observed a model move a toy dog towards a toy house, the door of which was either open or closed. Regardless of the state of the door the model always made the dog enter the house via the chimney. When children were allowed to copy, the door of the house was left open. The infants were significantly more likely to move the dog down the chimney when the door had been open during the demonstration (81%) than when it had been locked (44%). Schwier et al. (2006) argue that children assumed that the model had a good reason for making the dog go down the chimney in the closed door condition, which made them more likely to copy this uncommon action. Using the Sylvia example from earlier, if Sylvia had paid attention to the size of her mum's oven, she may have understood that the constraints which applied to her mum did not apply to her. She may therefore only have cut off the ends of the joint if she too had a small oven. The principle of rational action explains why children sometimes selectively imitate the actions they see another person doing: they understand that the constraints affecting the model (e.g. holding the blanket around them; the door to the house being locked) do not apply to them and so do not copy the model's actions exactly but emulate the goal.

However the principle can also explain why children sometimes display high-fidelity imitation (also termed over-imitation, Lyons, Young & Keil, 2007). High-fidelity imitation refers to the tendency to copy actions that are clearly inefficient towards performing a goal. According to the principle of rational action, children assume that the agent had a good reason, albeit not clearly understood by them, for performing the action that they did (e.g. putting the mouse down the chimney when the door is open; touching the lamp with one's head when one's hands are free) and so copy all actions faithfully. It has similarly been argued that pre-schoolers copy a model who performs clearly inefficient actions because they assume that the model had a good reason for doing so (e.g. Horner & Whiten, 2005). The principle of rational action can thus explain both selective and high-fidelity imitation, which indicates good explanatory power (it explains both the presence and absence of a phenomenon with the same rule). However the idea that infants possess such a principle has received some challenges both from experimental evidence and on a theoretical level.

Gergely et al.'s (2002) head-touch study has come under criticism, most strongly from Paulus and colleagues (Paulus, Hunnius, Vissers & Bekkering, 2011). In particular they argue that the head-touch action in the blanket condition is very difficult for infants to do because they cannot bend at the waist whilst holding their arms in front of them. Paulus et al. (2011) demonstrated that the likelihood of 14-month-olds performing the head-touch was affected by how easy it was for the infants to copy the model's action (e.g. they imitated more faithfully in conditions where the model's hands were placed on either side of the light). This would suggest that it is motor resonance – how well the model's action can be mapped onto the child's own motor repertoire – that determines imitation fidelity, not rational action. A similarly low-level interpretation of the data was formulated by Beisert, Zmyj, Liepelt, Jung, Prinz and Daum (2012) who suggested that the blanket condition is more perceptually salient, and may have distracted infants from the fact that the model used their head to turn on the light. When 14-month-olds were given a habituation period to get used to the distracting blanket, they imitated the head-touch just as much as in the no-blanket condition.

Similar caution can be levied against Schwier et al.s study (2006). Their results can be explained by low-level perceptual processes as suggested by Beisert et al. (2012). It is possible that children copy a model's actions more faithfully when the set-up used by the child matches the set-up used by the model more accurately. For example, in the closed door condition the set-up for the child does not match the set-up used by the model (as the door was open for the latter and closed for the former), whereas it does match in the open door condition. The mismatch between the two set-ups may have encouraged the child to deviate from the original action sequence more in the closed door condition.

It could be argued that this is a Straw Man approach: dismissing some of the studies supporting the idea of a principle of rational action instead of critiquing the principle itself. However there are theoretical objections raised against the idea of such a principle in infancy. Paulus (2012a) argues that "a principle of rational action" would also require infants to possess a number of other abilities. Firstly, to be able to evaluate other people's actions as rational, children need to understand that people are capable of performing some actions and not others. This would allow them to grasp the most efficient action *for that agent* to perform to achieve their goal. Children under 3 years do not seem able to reason about agents' action capabilities, that is, the range of actions and movements that agents are able to perform (Paulus & Moore, 2011), which makes it unlikely that infants can do so. Secondly, infants need to be able to evaluate the efficiency of other people's use of different body parts. They also need to be able to relate this evaluation to their own body, effectively deciding whether what is most efficient for other people is what is most efficient for themselves. But it is not until the third year of life that infants can map other people's body topography onto their own (e.g. after seeing stickers placed on another person's body, children under 30 months cannot reliably place stickers on the same locations on their own body; Brownell, Nichols, Svetlova, Zerwas & Ramani, 2010). Infants do not therefore seem able to map efficiency judgements about other people's actions onto their own bodies. Thirdly, if infants can imitate rationally then they require the ability to engage in what is known as counterfactual reasoning. In the head-touch study it is assumed that infants understand that the model in the blanket condition could have used their hands if they had not been holding the blanket (Perner, Sprung & Steinkogler, 2004). This ability to reason about possibilities under alternative situations is counterfactual reasoning. However this ability has not been demonstrated in children younger than 3 years (Harris, German, & Mills; 1996; see also Rafetseder, Cristi-Vargas & Perner, 2010; Rafetseder, Schwitalla & Perner, 2013). Beck, Robinson, Carol and Apperly (2006) have also shown that children under 6 years cannot reason about what alternative actions an agent could have done in a certain situation. From Paulus' objections it seems unlikely that infants possess the complex cognitive abilities to evaluate other people's actions in rational terms. The theoretical objections to the principle of rational action suggest that the data should be interpreted using processes that do not require an understanding of goals, which are supported by evidence (Paulus et al., 2011a; Beisert et al., 2012). Whilst one may be tempted to forego all discussion of goal understanding in infancy, there is an alternative theory of imitation that refers to both goals and non-goal processes, which is the focus of the following section.

The goal-directed theory of imitation (GOADI)

As mentioned above, there is little evidence that infants use an understanding of intentions to guide their imitation. Similarly if infants were imitating using the principle of rational action, this would require a number of abilities that do not develop until later in childhood. There is indeed evidence that infants' imitation can be explained without reference to complex mental state understanding or rational action evaluations. In particular, a point made in the above sections is that imitation in infancy is affected by the infants' own action experience (Hunnius & Bekkering, 2014; Paulus et al., 2011a). This idea comes from an important theory in the field of action understanding: the ideomotor account. The ideomotor account (e.g. James, 1890) posits that movements (internal motor programs) are encoded in terms of their effects (perceived sensory consequences). If a movement and effect co-occur enough times then the cognitive representation of that effect is associated with that movement – if I see K occur enough times after doing M then I learn that M leads to K (Hommel, 2009). This association is bi-directional: seeing an effect primes the movement associated with said effect, and observing a movement leads you to expect the effect associated with it (Paulus, 2014).

The ideomotor account of action has been posited as an explanation for children's copying behaviour. It forms a key component in a theory of imitation formulated by Wohlschläger and colleagues known as the Goal-Directed theory of Imitation (the GOADI account: Bekkering, Wohlschläger & Gattis, 2000; Wohlschläger, Bekkering & Gattis, 2003). This theory was first described by Bekkering et al. (2000) as an alternative to direct-mapping theory (such as Meltzoff's AIM account) which posited that humans have an innate ability to match an observed movement in another person with a similar (but non-observable) movement in themselves. In contrast Bekkering et al. (2000) argued that when one observes an action (e.g. scratching one's head) one does not represent it as a unitary motor pattern (e.g. the motor pattern of scratching one's head). The process of imitation rather has five propositions or rules:

- Decomposition: when one observes actions, these are broken down into their perceived goal aspects (the end goal of the action, how it was done, with what effector it was done…)
- Selection: only a few of these aspects are chosen due to working memory constraints
- Hierarchy: the selected goal aspects are hierarchically organised, with goals being prioritised over the means (like effector choice and movement paths)
- The ideo-motor principle: selected goal aspects elicit the motor program with which they are most strongly associated.
- General validity: this process is the same for adults, children and animals. The main difference between them is at the selection stage, as working memory capacity differs greatly between the types of agent.

The GOADI account thus combines both goal understanding processes and basic action-matching mechanisms to explain imitation. Support for GOADI came from work showing that when actions are seen to have clear goals, children tend to reproduce those goals more faithfully than the specific movements involved. Bekkering et al. (2000) conducted a series of studies where 4- to 6-year-old children observed a model demonstrate contralateral arm movements that either terminated on a visible end point (touching a dot on a table) or did not terminate on a visible end point (touching a blank spot on the table). They found that children copied the contralateral arm movement more faithfully when the dots were absent than when they were present. This was argued to be evidence that, in the absence of a visible goal, movements are more likely to be copied as they are retained during the selection phase after action decomposition. Gleissner, Meltzoff and Bekkering (2000) replicated this finding in 3-year-olds: children showed more errors when copying movements terminating on a body part (e.g. touching one's ear) than when the errors terminated near the body part (grasping the air near an ear). Both studies also showed that when the goal remains constant and less attention needs to be devoted to it, children can focus on reproducing the exact movement involved and copy it more faithfully (Bekkering et al., 2000; Gleissner et al., 2000). These studies were taken as evidence that different aspects of the motor program could be highlighted for imitation and that goals were given a higher place in the hierarchy than movements.

A similar finding was reported in infants by Carpenter, Call and Tomasello (2005). In this study 12- and 18-month-olds observed an adult either hop or slide a toy mouse across a mat towards a toy house (House condition) or towards a blank location (No House). Children copied the hopping movement significantly more faithfully in the No House condition than in the

House condition. In contrast they placed the mouse in the correct location far more often in the House condition. Such findings suggest that if there is no observable goal infants copy the movement more faithfully, which fits with the hierarchy of goals suggested by GOADI (Wohlschläger et al., 2003). When children understand the goal of an action (e.g. touch your ear; put the mouse near the house), the motor programme most strongly associated with that goal is activated, leading children to omit specific details of the action sequence (as these motor programmes seldom contain details such as "hop the mouse this way" or "cross your arm in front of you when you touch your ear" as we are unlikely to have acted often in this way; Wohlschläger & Gattis, 2002). GOADI thus posits imitation in infants and children to be goal-oriented, with effects and end goals prioritised over movements. It draws upon the ideomotor principle of action-effect associations and explains why movements are imitated more faithfully when no goal can be attributed to them. Nevertheless there are criticisms of this theory that should be considered.

Bird, Brindley, Leighton and Heyes (2007) argue that a problem with GOADI is the implicit assumption that imitation involves special processes beyond those involved in ordinary perception and action control (e.g. attention direction, working memory…). GOADI assumes that imitation is necessarily goal-driven, and prioritises goals as the essential features of actions to be reproduced (beyond other action features such as the movement). Bird et al. suggest that imitation does not require specialist, goal-focussed processes and instead can be accounted for using generalist features of stimulus-response association. To demonstrate this Bird et al. (2007) conducted a replication of a study by Wohlschläger et al. (2003) where adults saw a model lift a pen and put it into one of two differently coloured cups. In the original study adults made more mistakes about how to grasp the pen (using the left hand, upside down) and how to put it into the cup (rotating it counter-clockwise and inserting it tip down) than over which cup to put it into. However Bird et al. (2007) were able to change this error pattern by highlighting different elements in the demonstration. In their replication adults observed a model take a pen and move it into a cup: in different conditions distinct parts of the demonstration were highlighted with a colour (the cup, the pen, the hand of the model or the specific fingers). The adults were then asked to reproduce the actions performed by the model over many trials, to induce automatic imitation (where imitation of the model becomes an unconscious reflex). It was found that adults made fewer errors on whichever element was coloured: for instance when the hands were coloured the adults would make more cup errors than hand errors, and vice versa in the cups-coloured condition. There was no overall preference for reproducing the goal (moving the pen into the cup) over copying the movement or the grip. Bird et al. claim that GOADI would have predicted that the goal (moving the pen into the cup) should have been copied regardless of what element was highlighted by colour. That they did not find this showed that there is no intrinsic preference for goals over movements and thus runs counter to GOADI's predictions.

Generalist hypotheses (Bird et al., 2007) would also suggest that children's imitation is guided by broad processes of visual attention and action control. With fewer things to focus on in the absence of external effects (e.g. the No House condition in Carpenter et al.'s study, 2005) children may be able to focus on the movement in more detail. They may be less distracted by the external effect and thus perform the movement more faithfully. This would explain imitation in these conditions without requiring goal understanding in children. In conclusion GOADI, whilst drawing upon the solid principle of ideomotor learning, claims that goals (as external effects) should be imitated more than movements which is not substantiated in the literature. Other theories of imitation should explain why goals and movements can be equally prioritised depending on the context. Two such theories will be reviewed in the next section – the association sequence learning model and the ideomotor approach to imitative learning.

Associative sequence learning (ASL) and the ideomotor approach to imitative learning (IMAIL)

GOADI predicts that, all other things being equal, when an action sequence is observed the end state (or goal) should be retained more and imitated more faithfully than the specific movements with which the goal was brought about. This prediction has been challenged by Bird et al. (2007) who showed that it is possible to prompt more faithful imitation of the movement rather than the goal. Similar findings to Bird et al. (2007) were reported by Leighton, Bird and Heyes (2010) who replicated this colour-error pattern and extended it to imitation of non-biological stimuli. In their study adults would make the same colour-error pattern when the actions were demonstrated by geometric shapes on a screen. This showed that the colour-error pattern could not have been due to intention attribution and imitation on this task was due to general processes such as perception and attention. The colour-error pattern was replicated in 4- to 6-year-old children by Mizuguchi et al. (2011). Such findings suggest that imitation is not essentially goal-oriented, as automatic imitation studies show it can be affected by the same processes that govern perception in general (e.g. attention directed towards perceptually salient stimuli). If imitation can be said to be goal-oriented, goals are not end states of actions but outstanding action characteristics (e.g. parts highlighted by colour). Whatever is perceptually emphasised is copied more faithfully by the imitator.

The above findings are compatible with the associative sequence learning (ASL) account of imitation described by Heyes and colleagues (Brass & Heyes, 2005; Catmur, Walsh & Heyes, 2009). According to this imitation is governed by general mechanisms of associative learning (Catmur et al., 2009). The ASL account argues that experience is a key factor driving children's ability to imitate. When I perform an action X, I can see the way it looks (sensory representation of action X) and I know its motor command (motor representation of how to do action X). When the sensory and motor representations of X co-occur enough times in a predictive way, such that “motor X leads to sensory X” then a sensorimotor action representation of X is formed. These action representations are excitatory, vertical associations whereby seeing X activates the sensory representation of X, and this triggers the motor representation of X. This priming of imitation can only occur if children have experience of those actions beforehand, either from watching other people or by observing their own movements, as if there is no sensorimotor linking then observing an action will not prime any motor representation.

A similar theory to ASL, formulated by Paulus (2014), is the ideomotor account of infant learning (the IMAIL approach). This theory builds on the action-effect coding principle previously explained: as in ASL every action is controlled by a bidirectional action-effect association. Repeated co-occurrence between a motor code and its sensory consequences creates this action-effect association. Thus wanting to elicit a particular effect activates the motor program associated with it. Similarly to ASL the IMAIL approach highlights the role of experience on children’s imitation: observing another person’s action will only activate a motor code in the observer if the action is in the observer’s motor repertoire. Once a bidirectional action-effect link is formed the degree to which an observed action stimulates the same action in the observer is due to the similarity between the observed and executed actions. If the way I see action X done by someone else is very similar to the way action X looks like when I do it, the sensory code of X (and consequently its motor code) is strongly activated. This is termed “motor resonance”.

ASL and IMAIL are very similar theories of action production and imitation: they both refer to the ideo-motor principle in that observed actions stimulate action production in the observer, most likely via the mirror neuron system (Rizzolatti & Craighero, 2004). They also both claim that sensory effects of actions are associated with that action’s motor code when the effect and the action co-occur in a predictive way. The main difference between the two accounts is on emphasis: ASL focuses on how bidirectional sensorimotor codes are first formed, whereas IMAIL focuses on how imitation occurs once these codes have been established (Catmur et al., 2009). ASL and IMAIL both claim that actions are imitated primarily in terms of their effects – these are not end states as GOADI would predict, but merely perceived consequences of actions (e.g. seeing an arm raised). Intentional action is represented in terms of these effects, so that when infants see an effect produced they can want to produce the same effect themselves (Paulus, 2014). An action’s effect is thus the common representational format between observed actions performed by other people and executed actions performed by oneself: it is the common denominator between other people’s actions and our own acts.

Both ASL (Catmur et al., 2009; Leighton et al., 2010) and IMAIL (Paulus, 2014) suggest that goals in the sense of intentions (i.e., goal-directed action) may affect imitation. However the base mechanisms of imitation do not require an understanding of intentions, as we can imitate via the low-level processes of associative learning and motor resonance. Thus, ASL and IMAIL both suggest that the ideo-motor system helps infants imitate needing to understand actions as either goal-oriented or goal-directed. However ideo-motor processes can be used to help understand action goals in the goal-oriented sense. Paulus' (2012b) paper on action mirroring makes a very similar point to Perner and Doherty (2005). He cites Jacob (2009; Jacob & Jeannerod, 2005) who pointed out that seeing someone perform a goal is not the same thing as understanding people's actions in terms of intentions. You can see someone grasp a mug and, using your own motor system, can form your own goal of grasping the mug. This is not automatic but will be possible if one has experience of the action and is used to seeing it cause an effect – this will enhance imitation of this action (Gampe, Prinz & Daum, 2015). But this is not the same as believing the other person wants to grasp the mug. You need an understanding of intention to represent the goal of an action as a person's intention: you can infer an action's effect using your motor system, but this does not equate to intention understanding. Similarly Uithol, van Rooij, Bekkering and Haselager (2011) argue that while mirror neurons help understand action effects, they could not be used to infer action intentions by themselves, as intentions are context-dependent and require abductive reasoning processes. This distinction is further strengthened by neuro-imaging evidence. Studies show distinct brain regions for the "mirror" system, used for imaging and reproducing other people's actions, and for the "mentalising" system which helps process other people's intentions (de Lange, Spronk, Willems, Toni & Bekkering, 2008; van Overwalle & Baetens, 2009).

The ASL and IMAIL accounts thus provide strong theoretical arguments for conceiving of the base mechanisms in imitation as quite simple: it involves a matching of learned responses to perceived stimuli, where sensory-motor codings are formed on the basis of action experience (Paulus, 2014; Ray and Heyes, 2011). This can occur without reference to goals, and does not require specific mechanisms beyond simple associative learning (Leighton et al., 2010; Mizuguchi et al., 2011). Imitation is not a specialised, innate mechanism, but can be explained via general theories of action control and is modified by learning and experience. However both theories acknowledge that imitation is rarely a simple case of action-effect matching in a vacuum. Imitation is undoubtedly affected by higher-order cognitive processes such as mentalising, but these abilities help modulate imitation, they are not necessary parts of it. These abilities will presumably only affect imitation when they have fully developed, which means their effects will only be observed in older children. I will therefore now move away from imitation in infancy, and examine how imitation is affected by other socio-cognitive abilities later in childhood.

3. Imitation after infancy – how growing cognitive and social faculties affect imitation

Having described the basic mechanisms of imitation in infancy I will now examine how this ability develops throughout childhood. Jones (2007) demonstrated that infants' imitation increases in fidelity throughout the first two years of life. Imitation of actions without salient effects (that is, arbitrary actions[1]) develops later (at around 16 months) than does imitation of actions with salient effects, around 8 or 10 months. The IMAIL account predicts that this is because arbitrary actions lack the salient effects that form common triggers for observed and executed actions (Paulus, 2012b), and both the IMAIL and ASL models suggest that infants have less experience producing actions without observable effects (Catmur et al., 2009). For action-effect codings to be formed for such actions, we rely on imitative partners who show us what our actions look like when they are performed. It therefore takes longer for imitation of arbitrary actions to develop, and this can be dependent on the child's own experience of being imitated. One may expect greater imitation of arbitrary actions with age: this is one of the findings observed after infancy.

One might be tempted to argue that imitation in pre-schoolers and older children is no different from imitation in infancy. If one were talking about the mechanisms involved in imitation, this would be accurate: Leighton et al. (2010) and Mizuguchi et al. (2011) have convincingly shown that imitation in adults and children is affected by general processes of action-effect matching. Imitation in both adults and children is driven by associations between perceived sensory effects and internal motor programs. However it is a different question altogether to say that the functions of imitation remain identical from infancy to adulthood. Nadel (2002, 2014) as well as Zmyj and Seehagen (2013) argue that imitation serves two functions throughout development: to promote skill acquisition and to foster communication and interaction with other agents. From the age of about 18 months infants spontaneously imitate one another in free play settings (Nadel & Fontaine, 1989). This spontaneous imitation peaks at around 30 months of age and has certain general characteristics: it involves referential use of objects, it is reciprocal, and follows conventional rules. However, this communicative

[1] It should be noted that "arbitrary" in this thesis will refer to actions without salient effects, in both game and non-game contexts. Some previous studies (e.g. Gardiner, 2014) have used "irrelevant" or "non-functional" as opposed to "relevant" or "functional" actions, but this does not apply easily to game contexts where one can perform an action that has no observable effect but is still relevant to the game. It also does not apply to ambiguous tasks where the (non-)functionality of an action is unclear to children, for example if an apparatus is opaque. "Arbitrary" thus applies to both game contexts (where arbitrary rules and actions are expected) and non-game situations, regardless of whether children think an action functional or not.

function of imitation disappeared once language was mastered, as 3-year-olds would use objects cooperatively but not imitatively (Nadel & Fontaine, 1989). Imitation may therefore serve as a transitory communicative language in preverbal infants (Nadel, 2002). As well as communication, imitation has also been shown to promote affiliation with one's partner in social learning situations. Carpenter, Uebel and Tomasello (2013) demonstrate that 18-month-infants who are copied by an adult are more likely to help that adult with a task than if the adult did not mimic them. Similarly Lakin and Chartrand (2003) observe that adults primed with prosocial language are more likely to mimic other people, suggesting a bi-directional relationship between mimicry and prosocial behaviour. Lakin, Jefferis, Cheng and Chartrand (2003) suggest that the unconscious urge to imitate originally served a communicative function, allowing individuals to be accepted into social groups, before evolving into a type of "social glue" sustaining relationships.

The complex functions of imitation do not go against the ASL and IMAIL accounts. Both theories stress that imitation is modulated by other cognitive processes with age. Paulus (2014) suggests that infants' growing awareness of their own body topography (which is still immature under the age of 2: Brownell et al., 2010) helps them explicitly reason about how the actions they see correspond to movements they themselves can do. He also argues that language development may help children acquire new ways of imitating, citing Rumiati and Tessari's dual-route theory of imitation (2002, 2004). This model suggests that imitation draws upon two possible routes: a direct visuo-motor mapping route which relies solely on ideomotor processes and working memory, or via an indirect semantic route that draws upon action representations stored in long-term memory (Rumiati et al., 2005). Having linguistic representations of actions can thus help children imitate via the semantic indirect route.

The mechanisms underlying imitation may thus be identical for infants and older children. However it should be noted that social learning nearly always involves factors beyond mere action reproduction and mimicry. Throughout development other cognitive processes begin to affect children's copying behaviour, and imitation comes to serve a communicative function where the replication of another's actions will lead to social consequences. Theories of imitation in pre-schoolers therefore need to consider socio-cognitive processes if they wish to explain how imitation develops throughout childhood (Paulus, 2014).

The development of imitation throughout childhood

Having clarified the need to consider other factors beyond ideo-motor and associative learning beyond infancy, I will now examine key developments in children's imitation throughout childhood. As mentioned above children's imitation of arbitrary actions increases with age (Jones, 2007). This is paralleled by the appearance of a phenomenon known as "over-imitation" or "high-fidelity imitation", which refers to the tendency of children to copy even meaningless actions demonstrated by a model. A seminal work illustrating this behaviour came from Horner and Whiten (2005) who compared chimpanzees and 5-year-old children on an imitation task. Chimpanzees and children observed a model who demonstrated a series of actions on a box before eventually retrieving a reward from the box. Some of the actions were necessary to get to the reward (e.g. opening the door to the reward) and some were irrelevant (e.g. opening a lid on top of the box to an empty compartment). The effects of the actions were sometimes clear because the box was transparent, and sometimes hidden because the box was opaque. Horner and Whiten found that whilst nonhuman primates only copied the irrelevant actions when the box was opaque, the children copied the irrelevant actions *even when it could be seen that they were irrelevant (i.e., non-functional) to getting the reward*. This finding has been extended beyond pre-schoolers, with multiple studies showing that it increases throughout childhood and is present even in adults (McGuigan, Makinson & Whiten, 2011; McGuigan, Gladstone & Cook, 2012; Moraru, Gomez & McGuigan, 2016; Whiten, Allan, Devlin, Kseib, Raw & McGuigan, 2016).

Imitation during childhood does not only become more faithful, it also appears to become more indiscriminate. Yu and Kushnir (2014) observed that 2-year-olds would copy a model's exact movements faithfully during a task only if they were primed to do so by playing a mimicry game with the model beforehand. In contrast 4-year-olds copied the model faithfully regardless of the type of priming training they received. Moraru et al. (2016) demonstrated a similar finding for children between 3 and 6 years. They observed that 3-year-olds' imitation was more faithful if the verbal prompt accompanying the demonstration indicated a more conventional aspect to the task ("I will show you how to do the task") than when it indicated flexibility ("I will show you one way to do the task"). For children above 4 years the type of verbal prompt did not affect imitative fidelity.

However this finding of indiscriminate imitation is paralleled by the development of the opposite ability: children become more able to be selective in their copying behaviour. By the age of 4 years children can track how reliable informants are based on bystander approval, and subsequently endorse labels provided by reliable informants over unreliable ones (Fusaro & Harris, 2008). This ability appears to go through developmental stages: Koenig and Jaswal (2011) observed that 3- and 4-year-olds do not so much prefer reliable informants but avoid unreliable informants. This was also observed by Pasquini, Corriveau, Koenig and Harris (2007) who found that whilst 4-year-olds will monitor each informant's overall accuracy, 3-year-olds tended to be distrustful of a model who had made one mistake, preferring to avoid previously inaccurate models' choices. These findings show that while imitative fidelity increases with age children also show more discriminate imitation. High-fidelity imitation is thus unlikely to be an uncontrollable, automatic process, so theories explaining it should explain why such selective imitation can also occur. The following sections will review different theories surrounding the appearance of high-fidelity imitation and selective copying in the pre-school years. In particular I will examine the direct perception hypothesis; the role of causal reasoning; the desire to affiliate with other people; and the effect of normativity and the conventional status of actions.

The direct perception hypothesis: how action understanding modulates imitation fidelity

As mentioned above both ASL and IMAIL argue that the mechanisms underlying imitation are not specialised or intrinsically goal-focussed. Other people's actions are imitated because of bindings between perceived sensory effects and associated motor programs. This can explain imitation in a parsimonious way without positing higher-order cognitive abilities in infancy. But both theories acknowledge that such higher-order cognitive factors can affect imitation once they are in place. One theoretical account that suggests how higher-order factors may affect imitation is the model of direct perception as formulated by Froese and Leavens (2014). This model claims that actions are perceived primarily in terms of their effects. When seeing someone pouring themselves a drink, one does not focus on the precise way they hold their hands or the angle at which they pour the cup. Rather one focuses on the overall goal of the action, which was pouring a drink. Less attention is paid to precise details and more to the overall goals of actions. Froese and Leavens argue that focussing on the specific movements of an action is cognitively harder to do than to merely reproduce the end goal. This is because one has to override the motor representation of actions associated with that goal and focus on copying all of the actions: if I see someone lifting a cup and drinking, it is harder to focus on reproducing the precise finger and arm movements involved that just activate my own motor program of "drink from the cup". The theory of direct perception thus predicts a somewhat counter-intuitive result: physical details and intelligibility are in conflict with one another.

There is substantial evidence that action understanding is affected by cognitive factors in a top-down way. Teufel, Fletcher and Davis (2010) review neurological findings which show that explicit Theory of Mind (ToM) beliefs affect action understanding and perception. ToM attribution encourages automatic gaze following (Teufel, Alexis, Clayton & Davis, 2010b), which shows that assuming an agent has beliefs biases one's attention as we expect agents to act in certain ways (e.g. to look in certain places). Liepelt, von Cramon and Brass (2008) also showed that if a model's finger movements seemed intentional, this resulted in a greater automatic imitation effect in the observer. Teufel et al. (2010) argue that attributing mental states to actions facilitates the sensory processing of said actions within the superior temporal sulcus (Blakemore & Decety, 2001), enabling a strong perception-action coupling. Support for the direct perception hypothesis also comes from the phenomenon of change blindness (Simons & Levin, 1998; Simons & Rensick, 2005) where even drastic changes to visual scenes go unnoticed by observers provided the overall meaning of the situation is unchanged. Perceiving the goal of an action means one does not need to analyse the specific movements involved, and should reduce imitative fidelity of the precise movements of that action.

It could be argued that this theory is just GOADI in disguise. Certainly the parallels are worth mentioning: the direct perception hypothesis claims that intentional action is primarily represented in terms of their goals, and GOADI claimed that goals are focussed on more than precise means in the hierarchy of action components. Both predict that goals will be focussed on more than means in reproducing actions. However, as mentioned above goals will not always be reproduced more faithfully than movements (Bird et al., 2007; Leighton et al., 2010; Mizuguchi et al., 2011). It could be said that the direct perception hypothesis is open to the same criticisms and weaknesses as GOADI (which are that it claims that goals are always prioritised over means, and requires a specialist goal-processing mechanism for imitation beyond normal visual processing abilities). But this is not the case: Froese and Leavens (2014) state that goals will only be a focus of imitation in the case of meaningful actions, where obvious goals can be attributed to the movements observed. Where actions are unintelligible (i.e. when they are arbitrary) children are not used to performing them as they are typically novel, so no known motor program can interfere with the production of the specific movements, which means that movements should be copied more faithfully than specific end states. This explains why high-fidelity imitation of arbitrary actions occurs, as the arbitrary action cannot be assumed to have a known goal which is already associated with a known motor program.

Supporting this, there is evidence that when the goal of an action sequence is emphasised by the model, children will prefer to copy the goal over the means. Elsner and Pfeifer (2012) conducted an imitation study where 3- to 5-year-olds saw a model move a toy sheep from a central platform either into one of two bowls (low salience condition), or moving into one of two salient locations (Nicky wakes up and decides to sit in the boat/on the bench). They also varied whether verbal cues emphasised the sheep's movement (Nicky goes up/down) or the goal (Nicky goes to sit in the boat/on the bench). When the children were asked to have a turn, they had to use a different platform where the movement and the goal were mutually exclusive: if they tried to copy the model's movement (e.g. Nicky goes up) then they would end up at a different goal to the model (either in the wrong cup/wrong location). Likewise if they wished to copy the goal (Nicky went to the red cup/boat) then they had to move the sheep in the opposite direction to the model. Elsner and Pfeifer found that if the model drew attention to the goal in their verbal description, children copied the goal of the action over the movement, bringing about the same outcome via different means. They showed no preference for copying the movement over the goal if the goal was not mentioned by the model. Elsner and Pfeifer also found that children copied the goal over the movement when the goal was highly salient (the bench or the boat) but did not show a preference for copying movements over goals in the low salience condition (when the sheep was moved into one of two bowls). These results show that meaningful goals, emphasised by either verbal cues or cultural relevance, encourage imitation of those goals over specific movements.

Elsner and Pfeifer (2012) found that when no verbal emphasis was placed on the goal of the action, and when the goal was not socially salient, children had no preference for reproducing the goal over the precise movements of the model. These conditions replicate those of automatic imitation studies as in these experiments the model places no verbal emphasis on the goal of the action and the end goal is arbitrary rather than socially meaningful (Bird et al., 2007; Leighton et al., 2010; Mizuguchi et al., 2011). Such studies find that in the absence of emphasis on goals, movements and goals are copied equally faithfully. Goals are not always replicated more than movements, but contextual cues make it more likely for the learner to perceive a relevant goal to the action, and they will then focus on that action more. The ASL and direct perception accounts are thus not exclusive: they may even be complementary with the former explaining the mechanisms of imitation and the latter describing how these mechanisms may be modulated with reference to action understanding.

The direct perception hypothesis explains why imitation of specific movements is reduced when those actions can be fitted into a wider, meaningful context. Context plays an important role in whether an action will be understood as having a salient goal (Hunnius & Bekkering, 2014; Uithol et al., 2011). If goals are arbitrary and not emphasised by verbal or perceptual cues, there is no tendency to copy them over movements. However if actions can be related to goals whether by relevant social cues or by verbal instruction, those goals will be preferentially copied over specific movements (Elsner & Pfeifer, 2012). The direct perception hypothesis does not so much describe the base mechanisms of imitation, but explains how these mechanisms are modulated by growing action experience and socio-cultural awareness. Given that pre-schoolers seem to attend more to goals when these are emphasised by verbal or sociocultural cues (Elsner & Pfeifer, 2012) this suggests that after infancy children begin to prioritise goals when imitating actions.

Children's causal reasoning abilities

As mentioned above, one explanation of high-fidelity imitation in children is the direct perception hypothesis, which states that perceiving the goal of an action can actually decrease precise imitation of the action's components. High-fidelity imitation of arbitrary actions occurs because no explicit external goal is associated with the actions, meaning that these actions can be imitated more precisely. A second explanation of high-fidelity imitation was formulated by Lyons and colleagues (Lyons et al., 2007; Lyons, Damrosch, Lin, Macris & Keil, 2011). Termed “automatic causal encoding” (ACE), this account suggests that children believe that intentionally demonstrated actions are causally meaningful to the task in question. Therefore children reproduce all actions that they see demonstrated because they mistakenly assume that they are all necessary to bring about the same effect. Lyons and colleagues formulated the ACE account following a number of findings: one study (Lyons et al., 2007) looked at imitation in 3- to 5-year-olds. Children in this study observed a model perform a series of actions to remove a toy dinosaur from a box. Some of the actions were necessary and some were arbitrary: all action effects could clearly be seen as the boxes were transparent. Children would reproduce arbitrary actions even if they had received training and were encouraged to try and avoid doing “silly extra things”. The children also imitated the arbitrary actions in the absence of the model, which the authors argued was evidence that they were not imitating just to please the model. Lyons et al. (2011) also showed that children performed arbitrary actions in competition settings, even when doing so worsened their performance overall. The only manipulation reducing imitation of irrelevant actions was when these actions were performed on a disconnected section of the apparatus (Lyons et al., 2007). The authors argue that this is because this violates the “contact principle” which states that objects can only mechanically affect one another when they touch one another (Spelke, 1994).

The ACE account explains high-fidelity imitation through distorted causal inferences. Children seeing a model demonstrate an intentional action mistakenly assume that these actions were causally necessary to obtain the effect in question. Note here that intentional is used as opposed to accidental, as children do not attribute causal status to actions that a model marks as a mistake (by saying “whoops, I didn’t mean to do that!”, Carpenter, Akhtar & Tomasello, 1998). However there are some challenges to the ACE account. One is that children will continue to imitate actions even if they are aware that they are causally unnecessary. Kenward, Karlsson and Persson (2011) had 4- and 5-year-old children imitate a series of actions, some of which were necessary and some arbitrary. They found that, when asked whether the actions were needed to retrieve the marble, children recognised that the necessary action was needed and that one could retrieve the marble without the arbitrary actions. There was however still a high rate of imitation of arbitrary actions in this study, showing that children would reproduce the arbitrary action regardless of whether they knew it was necessary or not. If children were only interested in reproducing causally necessary actions then they should not reproduce actions they know to be arbitrary, even if they are demonstrated intentionally. Similarly Marsh, Ropar and Hamilton (2014) conducted a study where 5- to 8-year-olds imitated models performing arbitrary and causally necessary actions. In this study children not only imitated arbitrary actions more faithfully with age, but older children were more likely to imitate arbitrary actions if they rated them as less causally necessary. The studies by Kenward et al. (2011) and Marsh et al. (2014) provide evidence that pre-schoolers will reproduce actions that they know to be arbitrary, which suggests that mistaken causal encoding is not driving their imitation.

Further evidence against the ACE account comes from Hoehl, Zettersen, Schleihauf, Gratz and Pauen (2014). They conducted a study where 5-year-olds were shown two ways of removing tokens from a box by two models: one used only efficient, relevant actions to remove the tokens and the other included irrelevant actions in their demonstration. If children saw the inefficient way first, then they would only switch to the more efficient way if it was modelled by a communicative, engaging model (who had played a warm-up session with the child and prefaced their actions on the task by getting the child's attention and saying "Watch!"). In contrast if the model was uncommunicative then children did not stop performing the action in the inefficient way. This shows that children were not affected solely by whether or not they saw the efficient solution: their imitation was also affected by *how* this efficient solution was demonstrated and the connection they had with the model. It should also be noted that when the first model used the inefficient solution, children showed quite high levels of high-fidelity imitation, even though children could see the effects of each action on the apparatus as it was transparent. They should therefore have been able to infer causal relations of the actions, and the fact that almost no children performed arbitrary actions in a no-demonstration control supports this. So in spite of the fact that they could see the actions to be arbitrary, 5-year-olds reproduced these actions and would not omit them unless shown how to do so by an engaging demonstrator. This speaks against the ACE account and suggests that ascription of causality is not the only factor affecting high-fidelity imitation in pre-schoolers.

A more moderate argument regarding children's causal inferences was developed by Gardiner, Greif and Bjorklund (2011) who observed that 3- to 5-year-olds were more likely to imitate arbitrary actions when a model verbally marked these actions as intentional (by saying "There!" whilst doing it) as opposed to when the action was accidental (by saying "Whoops!"). Gardiner (2014) extended this by demonstrating that it is only when children cannot infer causal relations by themselves that they use intentionality as a cue to relevancy. In her study she showed that if action effects were unknown (by making the apparatus on which they were performed opaque) and children did not infer causal relations from observation, they imitated the model's actions more when they were intentional rather than accidental. In contrast when the effects of the actions could be seen, children would not perform arbitrary actions regardless of whether they were intentional or not. This theory provides a more measured view of children's causal reasoning and explains why they may sometimes defer to copying other people when action effects are unknown. But this theory only predicts that pre-schoolers should imitate non-functional actions when action effects are ambiguous: it does not explain why actions that are *clearly* unnecessary are still imitated (Horner & Whiten, 2005; Kenward et al., 2011). It also does not explain why high-fidelity imitation of arbitrary actions increases with age (as has been found by several studies: McGuigan et al., 2011; Whiten et al., 2016; Yu & Kushnir, 2014) as children's understanding of causality improves with age (McCormack, Butterfill, Hoerl & Burns, 2009). To summarise, causal reasoning abilities may help children understand actions, but as social learning situations often involve more variables beyond action causality, other factors are required to help understand pre-schoolers' imitation of arbitrary actions. Any theory focussing mostly on causal reasoning therefore lacks explanatory power to explain high-fidelity imitation.

The social side of social learning

As mentioned above children will imitate clearly arbitrary actions. High-fidelity imitation cannot solely be due to children reasoning about whether certain actions bring about an observed effect. Over and Carpenter (2012) emphasise that social learning is inevitably "social". If this is the case, then the quality of the interaction between the model and the learner should affect imitation fidelity. Evidence for this has been demonstrated in multiple studies. Nielsen looked at how communicative cues affected imitation in 18- and 24-month-olds (2006, Experiment 3). In this study children observed a model press a switch on a box before opening said box: the model either used their hand or a tool to press the switch. The model was either very sociable (they met the child before the study began; throughout the task they smiled and frequently made eye contact with the infant) or acted in an aloof manner (they did not build rapport with the child before the task; they avoided eye contact with the child during their demonstration). Eighteen-month-olds were more likely to copy the model's use of the tool to open the box in the social condition; the 24-month-olds would copy the tool use at equal rates for either type of model, but were more successful at opening the box in the social model condition. Nielsen argues that the rapport with the model made infants above 18 months more likely to copy their exact tool use to sustain the interaction.

With regards to high-fidelity imitation, Over and Carpenter (2012, 2013) argue that children's imitation will be more faithful if the child has a "social goal". Imitation is not about performing the task in a particular way, but about expressing likeness with the demonstrator, to affiliate with them. Evidence for this type of behaviour comes from Nielsen and Blank (2011) who showed that 4- and 5-year-olds, after seeing two models demonstrate different action sequences to open a box, preferred to copy the actions of whichever model was present during the children's own turn. Although children had seen the two ways of opening the box, they would copy the method used by the present model. Similar results were found by Nielsen and

Tomaselli (2010) – they conducted an imitation study with children aged 2 to 13 years. Children were given an artificial fruit to open, and then shown another way of opening it which included arbitrary actions. Children who had been successful in opening the box without the arbitrary actions would begin to demonstrate them if the model used them. Children showed a tendency to bring their copying behaviour in line with that of the model. Therefore whilst children know how to perform the task in another, simpler, way, they prefer to use the solution demonstrated by their interactive partner to affiliate with them. It is also possible to encourage the goal to affiliate which increases high-fidelity imitation. Over and Carpenter (2009) showed 5-year-olds a video depicting a shape being ostracized by two other shapes playing catch or a neutral video showing two shapes and a butterfly. They found that, following a model's demonstration of manipulating a tool on a box to turn on a light, children who had seen the ostracism video were more likely to copy the model's exact movements than children who had seen the neutral video. Children copied the action outcome at equal rates between conditions, showing an equal motivation in both conditions to achieve the effect. The only difference was the matching of the model's exact movements (e.g, holding the tool in a certain way). The authors argue that this shows that ostracism enhances the recollection of social information and/or primes a goal of affiliation with the model.

Further evidence for the effect of the model-learner relationship on imitation comes from comparisons of video and live models. In imitation tasks children usually observe a model perform a series of actions on an apparatus. If it were just a matter of learning which actions to produce, then it should not matter whether the demonstration comes from a real-life person or from a video demonstration. But studies have shown that live models are imitated more faithfully than actors on video. Nielsen, Simcock and Jenkins (2008) presented 24-month-olds with either live or video models showing children how to open several boxes using a specific tool on each box. Whilst the number of boxes opened did not differ between conditions, the children imitated the model's use of the tool significantly more in the live-model condition than when the model was on video. However this difference disappeared when the model could communicate on video by means of a CCTV link: when this occurred children copied the model's tool use significantly more than when the model was in a non-interactive video display. This shows that the crucial factor encouraging faithful imitation in live models over video displays is the contingency and interaction between the model and the learner (Krcmar, 2010). Evidencing preference for live models over video actors beyond infancy, Marsh et al. (2014) showed that children between the ages of 5 and 8 years also copy live models more faithfully than models on video.

The above studies show that aspects of the model-learner relationship such as model reciprocity and the drive to affiliate encourage high-fidelity imitation. But there are important caveats to be considered here, particularly from studies looking at how imitation occurs in third-party contexts. One is that high-fidelity imitation can occur in the absence of direct interaction with the model. Nielsen, Moore and Mahomedally (2012) had 4-year-olds watch an adult show another adult how to retrieve a toy from a closed box using a series of actions, some of which were arbitrary (e.g. tapping the top of the box three times). When children were given the box after seeing this demonstration, they would copy the arbitrary actions displayed by the model. This occurred even if children had previously been able to open the box by themselves without using the arbitrary actions (see also Nielsen & Tomaselli, 2010). Children's imitation was also unaffected by whether the adult who had taught the action was present in the room. This shows that the quality of the model-learner relationship is not the only factor affecting imitation, as children imitate faithfully even if the original teacher is not present. A related finding was observed by Shimpi, Akhtar and Moore (2013) who looked at imitation in 19- and 24-month-olds. They found that children were far more likely to imitate a model in a direct interactive setting if they had previously played a warm-up game with that model. However, familiarity with the model did not affect the likelihood of children imitating that model when seeing them demonstrate actions to a third party. Children imitated familiar and unfamiliar models at equal rates when they were observing actions demonstrated to others. This shows that the quality of the model-learner relationship only improves imitation fidelity in direct interactive settings, and it is not necessary for children to imitate faithfully when merely observing others.

The results from third-party imitation studies suggest that the dynamic between learner and teacher is not the only determinant of imitative fidelity. This makes sense if we consider that dyadic interactions are often situated within the wider context of cultural exchanges. Nielsen et al. (2012) argue that high-fidelity imitation following third-party demonstrations indicates that such imitation is used to acquire cultural traditions from those around us. Copying the purposeful actions of others, even if they are unnecessary and not modelled directly to us, is a useful strategy in order to acquire culturally-driven behaviour. Such cultural behaviour goes beyond the learner and teacher dyad, and imitation can be used to learn behaviour related to a social group rather than an individual. This leads me to discuss another factor affecting imitation: emphasis on the conventional status of actions.

The role of convention and normativity

A fourth explanation of why high-fidelity imitation occurs in children is normativity. Researchers focussing on normativity suggest that when children are shown how to perform a new task they infer that the demonstrated way is the proper way of doing it. The demonstration is interpreted as a rule or norm which should be followed. The normativity account has primarily been formulated by Rakoczy and colleagues (Rakoczy, Warneken & Tomaello, 2008;

Schmidt, Rakoczy & Tomasello, 2012; Keupp, Behne & Rakoczy, 2013; Keupp, Bancken, Schillmoller, Rakoczy &Behne, 2016). According to Rakoczy and Schmidt (2013) norms have certain characteristics: they are conventionally constructed (and therefore to a certain extent arbitrary); they are context-dependent and only apply in certain situations; and they provide us with a standard by which to act and by which to evaluate other people's behaviour. Norms are not merely statistical expectancies about what is the most frequent response in a given situation X: norms relate to what *ought* to be done in situation X (Southwood & Eriksson, 2011).

The normativity account suggests that high-fidelity imitation occurs when children believe that the way they see the task performed is the "correct" way to perform the task in that context. Supporting evidence for this interpretation has come from several studies: Schmidt, Rakoczy and Tomasello (2011) found that 3-year-olds imitated a model's actions more faithfully when the model appeared to demonstrate known actions than when they appeared to be inventing actions. Keupp et al. (2016) also conducted imitation tasks with 4- to 5-year-olds. In one condition the conventional nature of the game was emphasised with a special label ("daxing"), and in the other the instructions simply emphasised the end goal of the game ("ringing the bells"). Children would imitate a model's arbitrary actions more when they were performed with the conventional prompt. However the authors also found that when the arbitrary actions resulted in a negative consequence for a third party (e.g. placing marbles in a box would mean none would be left for the experimenter), children were far less likely to imitate them. These findings show that not only do children imitate unnecessary actions when they have conventional status, they do so in a flexible way depending on the context (as would be predicted by normativity theory). It can also be pointed out that Keupp et al.'s (2016) finding fits with Gardiner's (2014) study as the former found high-fidelity imitation with a conventional prompt and both found selective imitation with an instrumental prompt.

Normativity theory not only predicts high-fidelity imitation of meaningless actions in a given context, it also holds that a proper understanding of social norms should lead to the capacity to protest against other people not following those norms (Rakoczy & Schmidt, 2013). There is evidence that children will enforce social norms when they see third parties deviate from them. Rakoczy et al. (2008) found that 3-year-olds, and to some extent 2-year-olds, critiqued a puppet for playing a game incorrectly, enforcing the rules of the game. Subsequent studies demonstrated that this protest is not automatic but affected by multiple factors. Children protest when a mistake is made in the appropriate context but not in a context where the rule does not apply (Rakoczy et al., 2009); they enforce conventional rules only for the specific group members to whom those rules apply (Schmidt, Rakoczy & Tomasello, 2012); and children protest more if a third party's mistake will result in negative consequences for someone else (Keupp et al., 2016). Normativity theory can therefore explain both high-fidelity imitation and protest towards deviant third parties.

There are certain parallels that can be drawn between normativity theory and the multiple-stance account from Nielsen, Kapitány and colleagues (Nielsen, Kapitány & Elkins, 2015; Kapitány & Nielsen 2015; see also Herrman, Legare, Harris & Whitehouse, 2013 for a very similar account). This framework argues that a foundation of human cultural evolution has been the development of ritual, and that humans are biased to interpreting certain types of actions as ritualistic (Herrman et al., 2013). Actions are viewed as ritualistic: a) when the action is causally redundant, b) when the action is repetitive, and c) when there is a specific, distinctive way of performing the action (e.g. "daxing" is distinct from "ringing the bells" in Keupp et al.'s study, 2016). On the basis of these cues a learner can interpret the actions of a model in one of two possible ways: one way is the instrumental stance, where the model's actions are interpreted as a personal choice, mainly task-driven, and can thus be deviated from. There is no cultural meaning attached to their actions and so no pressure to conform to the way they do it. The other way is the conventional stance, where the model's actions reflect a social norm and actions have a cultural significance beyond their instrumental effects. To relate this account back to Rakoczy's framework, actions are more likely to be construed as normative when the conventional stance is active: when this is the case children will imitate more faithfully and should protest more to seeing deviant third parties.

The multiple-stance theory has also been used to explain why children display high-fidelity imitation of irrelevant actions. Wilks, Kapitány and Nielsen (2016) conducted a study where 4- and 5-year-olds watched videos of either individuals or group members (marked by wearing identical t-shirts to observers) performed actions on a set of boxes. The individual would always perform actions that led to the box being opened. The group member only ever performed causally irrelevant actions. Wilks et al. found that when both videos were demonstrated in an instrumental way (i.e. no ritualistic cues) children copied the successful individual over the unsuccessful group; however when the group's actions *were* marked by ritualistic cues (humming, bowing…) children would copy these actions over the individual's successful actions (similar findings come from Herrmann et al., 2013). Imitation can thus be increased by highlighting the conventionality of the actions in question. Given that the actions performed by the individual in Wilks et al.'s study (2016) were equally observable in the instrumental and conventional conditions, children were not causally confused about the effects involved in the tasks but motivated to copy the arbitrary group actions. The idea of instrumental and ritual stances complements the theory of normativity by explaining how normativity can be ascribed in different situations.

The concept of normativity can explain both high-fidelity imitation and third-party protest in children. Normative protest begins to occur at around the age of 2 years (Rakoczy et al., 2008), hence at around the same time as high-fidelity imitation (Jones, 2007). It could therefore be argued that an awareness of the conventional status of actions drives both protest and high-fidelity imitation. However there are some limitations to be considered. As mentioned by both Rakoczy and Schmidt (2013) and Kapitány and colleagues (Kapitány et al., 2016) normativity is not automatic. Normative status is only applied to actions in certain situations: children do not blindly imitate but reason about the consequences of their imitation, and do not imitate faithfully if it means others cannot play the game (Keupp et al., 2016). Other factors affect children's imitation when normativity cannot apply (for instance when synchrony and conventionality cues are absent). For example, Nielsen and Blank (2011) conducted a study in which 4- to 5-year-olds observed two models display two ways of opening the same box. One of the models left and the remaining model asked the child to open the box. Children were more likely to copy the actions used by whichever model was present, with no preference for either type of action. In this case children did not learn a norm (as this would have presumably led them to copy the task the first way they saw it done) but copied whichever model was present at the time. Wood, Kendal and Flynn (2013b) also showed that 5-year-olds can acquire multiple ways of performing the same task and will use both solutions flexibly. In such cases children do not seem to learn "the correct way" to perform a task: they learn multiple ways and use these solutions flexibly.

There are also theoretical objections against the normativity account. As seen above a lot of work looking at children's understanding of norms has used protest towards third parties as evidence of norm understanding (Rakoczy et al., 2009; Schmidt et al., 2012; Keupp et al., 2013; Keupp et al., 2016). Children verbally protest towards third parties around the age of 2 (Rakoczy et al., 2009). However Brandl, Esken. Priewasser and Rafetseder (2015) point out that protest can be caused by other factors: a) the deviant third party not listening to the model, b) a mismatch between what the deviant model says they're going to do and what they actually do, or c) the inability of the deviant third party to follow a rule. As such protest in and of itself is not sufficient to establish normative understanding. Brinck (2015) makes a similar objection to Rakoczy's methodology. Normativity implies that there is an ideal behaviour which is the "correct" way of performing the task (e.g. "daxing") in question. However corrective protest towards a deviant third party may simply be used to show how daxing is *usually* performed, not how it *should* be performed. Brinck argues that children see the deviant puppet not as violating a social norm (e.g. play peacefully, be nice, take your turn) but merely as not participating in the practice of daxing. Children do not believe the puppet is daxing in the wrong way, but simply not daxing at all, and thus they tell them how to dax properly. Correcting a misunderstanding is not the same as enforcing a social norm, and full-blown normative understanding is unlikely to develop until later in childhood (Köymen, Lieven, Engemann, Rakoczy, Warneken & Tomasello, 2014).

To summarise, normativity explains why children imitate arbitrary actions, even when they can see that those actions are unnecessary. An understanding of rules helps explain why children will protest against deviant third parties and display high-fidelity imitation, even of unnecessary actions. Normativity is not automatically attributed to all situations but is context-dependent: cues to conventionality may enhance the likelihood of normative status being attributed to actions. However children will sometimes deviate from actions shown to them by a model (Wood et al., 2013b), and normativity is not attributed in all situations. There is also some debate as to how normative children's understanding of rules is (Brandl et al., 2015), as it could be explained with reference to more descriptive rules (Brinck, 2015). Therefore other factors should be considered when normativity cannot apply.

Overall, the theories discussed above all point to different factors to explain why pre-schoolers display high-fidelity imitation. The theories suggest different functions of imitation: the direct perception hypothesis and the ACE account situate imitation within the context of reproducing observed goals. If an action seems purposefully directed towards a goal then actions unrelated to that goal can be omitted; in contrast if no goal is emphasised for that action then movements and goals are imitated equally faithfully. Imitation can also help affiliate with the model: interactions with the model reinforce one's motivation for performing the task in a certain way, and the threat of social exclusion enhances one's desire to perform the task in a certain way. Copying other people can also be used to acquire relevant cultural norms. Understanding that people have specific, conventional ways of performing a task enhances faithful imitation of otherwise arbitrary actions on these task. These theories are not mutually exclusive: rather they all highlight the importance of different factors in children's imitation, affecting the likelihood of faithful copying. They thus attempt to explain faithful and selective imitation at different ages. The next section will review the main factors that the above theories suggest affect imitation, discussing evidence for them in turn.

4. Factors encouraging high-fidelity imitation

The preceding review has shown that the mechanisms of imitation based on associative learning between actions and effects. However the functions of imitation are more complex, and over the course of development higher-order socio-cognitive abilities influence and control these lower-level mechanisms. I have reviewed multiple theories that attempt to explain why high-fidelity imitation occurs. These theories implicate different factors in children's social learning which will now be reviewed to give a clearer picture of how to investigate imitation in childhood. The factors will be grouped under the headings of model factors and action-related factors.

Model factors

The identity of the model being imitated and the quality of their relationship to the learner have both been implicated in children's imitation. Live models are copied more faithfully than models on video: this effect is present in 2-year-olds (Nielsen et al., 2008) and is still present by the age of 8 (Marsh et al., 2014). This effect is driven by the contingency and interaction between the learner and the model: one waits until the other is done before doing something else (Nielsen et al., 2008; Kcrmar, 2010). It should be noted that a sociable model only seems to encourage precise imitation of a model's exact movements, not of the end goal itself. For example, for children aged 24 months a sociable model will encourage precise reproduction of a model's tool use (Nielsen et al., 2008), but the overall goal is reproduced just as much if it is modelled by an aloof adult (Nielsen, 2006) or learned by observation in a third-party context (Nielsen et al., 2012; Shimpi et al., 2013). Similarly if children are exposed to a video depicting ostracism, they will imitate a model's movements (i.e. manipulating a tool a certain way) more faithfully than if they are exposed to a neutral prime, but they reproduce the goal of the movement (i.e. turning on a light in a box) equally faithfully regardless of the type of prime. High-fidelity imitation of the model's precise actions is thus increased by interactions with an engaging model.

Other model factors are children's preferences to copy (or avoid) specific models. Wood, Kendal and Flynn (2013a) conducted an extensive review of model-based biases in children, where they argue that children show tendencies to copy certain types of models. They will copy models who intend to teach (who display ostensive pedagogical cues); models who are proficient; models belonging to groups that have a reputation for being proficient; models that resemble the child themselves; and models who have a high status. There is substantial evidence to support these claims. Children's ability to determine proficient models is particularly flexible: for instance 3- to 5-year-olds will prefer to question peers about toys but adults about food (Vanderborght & Jaswal, 2009). Children learn to assess an informant's previous reliability and use it to guide their decision-making (Fusaro & Harris, 2008). The ability to evaluate reliability improves with age: at age of 3 children are relatively inflexible in their judgements, preferring to avoid models who have made one mistake rather than track overall reliability (Pasquini et al., 2007). Koenig and Jaswal (2011) remark that 3- and 4-year-olds show a marked aversion to endorsing labels from models who are marked as incompetent in one area, even if the task is in a completely different area. This shows that children aged 4 years and under display a domain-general reluctance to trust "silly" models. Bernard, Proust and Clement (2015) observed that while 4- and 5-year-olds will prefer to endorse labels provided by an unreliable consensus, 6-year-olds will prefer to endorse a reliable dissenter. As children age they get better at evaluating the reliability of the model and can go against the pressure of an incorrect majority – this ability is still underdeveloped at age 4 (Haun & Tomasello, 2011) but seems to be in place by age 6 (Bernard et al., 2015).

To summarise, there are multiple factors relating to the model that increase imitative fidelity. These are if the model is seen as proficient and if they interact directly and in a sociable way with the learner. After having considered characteristics of the model, I will now review how characteristics of the action affect the likelihood of high-fidelity imitation occurring.

Action factors

As mentioned by Gardiner (2014) children aged 3 to 5 used their causal reasoning abilities to guide their imitation of a model's actions. If actions could clearly be seen to be irrelevant to the model's stated goal then it did not matter if they were intentionally performed or not, they were not reproduced as frequently as necessary actions. However when the effects of actions were unknown (because the apparatus was opaque) children would copy the actions more faithfully when they were demonstrated as intentional. This suggests that by 3 years children seem to use both their own causal reasoning capabilities and their sensitivity to other people's verbal statements (accidental versus intended actions) to evaluate action importance. In Gardiner's study the demonstration and task was related to retrieving a toy. The actions were thus all stated with the end goal of retrieving the toy from the box. If actions could clearly be seen to be unrelated to helping achieve this goal (either because the box was transparent or the model said "Oh! I didn't mean to do that!") then children did not imitate these actions as often. In contrast when the effect of the actions was unclear but the model still performed them intentionally then children seemed more likely to copy the actions faithfully. This suggests that when children can relate actions to specific goals they are more likely to only produce actions that seem relevant to that goal. This would fit with the direct perception hypothesis formulated by Froese and Leavens (2014): if an action can be related to a goal then actions that are clearly relevant to that goal will be imitated. This may also explain why Horner and Whiten (2005) found high-fidelity imitation of irrelevant actions with 3- to 4-year-olds using a similar paradigm to Gardiner (2014). Horner and Whiten noted in pilot testing that children believed the goal of the demonstration to be about copying the model, and thus reproduced even irrelevant actions faithfully. In their study they provided children with limited verbal instruction, whereas the children in Gardiner's study were explicitly told that the demonstration and the imitation task were all about retrieving the toy. It is therefore possible that the goal of "retrieving the toy" was emphasised more in Gardiner's study which led children to rely on their own causal reasoning abilities more. From these studies we can conclude that the effects of actions influence their imitation: if actions relate to an observed goal then the necessary components of those actions will be copied more faithfully.

Children also show greater imitation of actions on objects than of actions on their own bodies. Objects have been argued to contain “affordances” which bias children to reproduce the actions associated with them (Gibson, 1986). Children learn to imitate actions demonstrated on objects earlier in infancy than body movements (Christie & Slaughter, 2009). Object-centred interaction has also been suggested to be the primary learning context for infants during the second year of life (Whitebread & O’Sullivan, 2011). Kim, Oturai, Kiraly and Knopf (2015) demonstrated that at 18 months, infants prefer to copy actions on objects than body movements. They also showed that when object actions led to salient effects (e.g. turning on a light, ringing a bell) infants imitated them more. However when body movements led to salient social effects (e.g. a third model mimics the child) this did not increase imitation over when the body movements led to no salient effects. This suggests that for children under 2 years, salient action effects may be a crucial factor in imitative fidelity for object-directed actions. As children this age did not show increased imitation for body movements that led to salient social effects, it is possible that social effects may only increase imitation for older children – this would fit with data showing a greater sensitivity to social cues with age (Marsh et al., 2014).

Children’s preference for copying object actions over body actions may be related to the ASL and IMAIL accounts of imitation. Paulus (2014) argues that salient, perceptual effects form the common representational format between seeing other people’s actions and our own actions. Seeing someone bring about an effect X leads me to perform the actions I have associated with effect X. It may take longer to learn to imitate body actions because often the perceptual effect is hidden or does not match the actions that I would do to perform it (I cannot tell how I look when I smile, but I can see someone else smile; Catmur et al., 2009). It takes longer to form associations between observed and performed movements in the absence of salient effects, because salient effects help focus one’s attention and are easier to remember. When action effects are known and can thus be inferred, we would expect that children will copy those action effects more faithfully.

However salient action effects cannot be the only factor driving imitation for children after infancy. As has been seen high-fidelity imitation of arbitrary acts increases throughout childhood and even into adulthood (McGuigan et al., 2011; Whiten et al., 2016). If actions can be understood within meaningful goals (e.g. they are directed towards achieving a known effect) then this goal is the effect that is copied (see also Paulus, 2012a). But as children get older they become more and more exposed to situations where there are seemingly no effects to actions, but they are nevertheless performed intentionally. Children above the age of 3 years will copy these types of actions (Gardiner, 2014) showing that by this age children do not solely copy actions leading to meaningful effects. Infants therefore show a tendency to copy only actions leading to salient effects. However older children will copy actions more faithfully if they are unaware as to the overall purpose of the action sequence, or if they infer the social goal of copying the model. Such a prediction is in line with the direct perception hypothesis (Froese & Leavens, 2014) which argues that understanding the purpose of actions should actually lead to lower imitation of actions. In contrast when no known goal can be inferred from an action then children should copy all parts equally faithfully, forming the social goal of copying the model.

Action factors that affect the likelihood of high-fidelity imitation are the type of action (on objects or on one's body); children's own action experience; and whether a salient goal can be attributed to that action. Younger children and infants seem to focus on reproducing salient action effects, whereas above the age of 3 years children will copy intentional actions even if they are unsure of their effects or even if they are useless.

To summarise, there are several factors that have been shown to encourage high-fidelity imitation: characteristics of the model and the actions involved will affect the likelihood of their being copied. In the final section I will outline how this thesis will help clarify the roles of these factors in more detail, and show how previous research has not controlled how the effects of these factors changes throughout childhood.

5. A systematic investigation of high-fidelity imitation throughout childhood

The above literature review highlights changes that occur in imitation from infancy into pre-school age. The same mechanism seems to underlie imitation in infancy up into adulthood (Paulus, 2014; Leighton et al., 2010; Mizuguchi et al., 2011). Imitation is driven by experience: associations are formed between perceived action effects and motor programs. These associations are bi-directional, which lead to action effects triggering the motor program when these effects are observed. The mechanism of imitation is thus not specially rational or goal-driven, but instead works via general associative learning (Catmur et al., 2009). However, as children age other factors begin to affect their interactions with others and shape their understanding of people's actions.

Different theories argue for the role of various socio-cognitive abilities in pre-schoolers' imitation. The theory of direct perception claims that children place the actions of others into meaningful, goal-oriented categories. They will thus show a predilection to copy actions relevant to those goals that are emphasised by the model (Froese & Leavens, 2014; Gardiner, 2014; Elsner & Pfeifer, 2012). Some emphasise that imitation also serves a social function, beginning as an early form of communication (Nadel & Fontaine, 1989). This is later replaced by language, but imitation continues to foster pro-sociality (Carpenter et al., 2013) and is enhanced by social cues such as interactivity (Nielsen et al., 2008) and the threat of ostracism (Over & Carpenter, 2009; see also Haun & Tomasello, 2011). In particular social factors encourage the imitation fidelity of specific movements rather than reproducing overall action effects. Going beyond the model-learner dyad, other theorists claim that imitation comes to be situated within the context of culture and norms. Actions presented as cultural conventions will be copied more faithfully (Wilks et al., 2016) and children tend to correct models who deviate from such conventions (Keupp et al., 2016; Schmidt et al., 2011). In summary after infancy imitation comes to serve not merely a function of information acquisition but also becomes a powerful tool in navigating one's socio-cultural environment (Zmyj & Seehagen, 2013; Over & Carpenter, 2012). The base mechanism of imitation remains the same, but it comes to be modulated by other cognitive abilities (in line with Rumiati et al.'s dual-route model of action understanding, 2005).

A key factor that affects imitation is age: this thesis looks at how children's copying behaviour changes throughout childhood in a standard successive-models imitation task. In this task children observe two models who show them different methods of performing the same task (e,g,: Nielsen & Blank, 2011; Keupp et al., 2013). Gauging children's reactions to the two models has been used to understand how they interpret the goal of the social learning situation. Using the successive-models paradigm across childhood can be used to determine how children imitate multiple models on the same task at different ages, and what affects their imitation.

In Study 1 I therefore present a study on imitation of successive models in children aged 2 to 12 years. Successive-models paradigms have been used to disentangle different theories of high-fidelity imitation (Nielsen & Blank, 2011; Keupp et al., 2013). In such studies children typically observe two models demonstrate two different ways of performing the same novel task, after which the child is asked to imitate. No previous studies however have looked at such a wide age range, which will show how children from toddlerhood to pre-adolescence react to models providing different information. Previous studies have also used either a puppet and an adult as the two models (Rakoczy et al., 2008; Keupp et al., 2013) or have allowed the two models to demonstrate their actions in one another's presence (Nielsen & Blank, 2011). The two models are thus not identical, and they also tacitly endorse other people doing things in a different way. Perhaps not surprisingly studies with inequivalent models have found that children endorse the higher-status model's actions (Keupp et al., 2013) whereas when the two models demonstrate their actions in each other's presence children show no preference for either model's solution but prefer to copy whichever model is present during their own turn (Nielsen & Blank, 2011). In Study 1 I therefore eliminated these confounds by having two adult models who demonstrate their actions in each other's absence. Children saw two models demonstrate two different versions of the same novel action, which they referred to by the same novel name (e.g. "lopping"). Children were allowed to imitate once after each model, and, after having seen the two models, they performed the task a final time in one model's presence. Seeing how 2- to 12-year-old children imitate the two models allowed me to infer how children imitate deviant models at different stages in childhood. There was a significant age-related change in the way children imitated on this task: notably as children aged they became more likely to copy the present model on each turn. Children under 3 years showed faithful imitation of the first model, but would not imitate the second model at all. Four- to five-year-olds were more likely to also imitate the second model than younger children, but were at chance as to who to copy once they had seen both models' solutions. Above the age of 6 years children began to copy whichever model was present, and this tendency grew stronger with age. In later childhood children copied whichever model was present without deviation.

Chapter 3 presents four follow-up studies to investigate this age-related change of imitation. Study 2 investigated the effect of labels on children's imitation. In Study 1 both models used the same label but then used different actions. As discussed above children protest against seeing third parties doing actions in different ways while announcing they would to the same. Children may dislike observing a mismatch between what the model says they will do and what they end up doing (Brandl et al., 2015), thus resisting to copy M2 in Study 1. To control for this possibility I included a control condition where the two models referred to their actions with different labels (e.g. one referred to their actions as "lopping" but the other model referred to theirs as "daxing"). If labels affect children's imitation then children should imitate the two models' actions more faithfully when the two models use different labels. Study 2 found that there was no effect of labelling on children's imitation (although there was an effect on adults' imitation) and particularly younger children, like in Study 1, kept imitating the first model's action, suggesting that the preference for the first model's actions is not driven by an inflexible use of labels.

Study 3 investigated the effect of motor inhibition on children's imitation of successive models in the first Study. Given that the base mechanism of imitation in younger children and infants is ideo-motor learning, they show a greater tendency to imitate actions they themselves can do (Paulus et al., 2011). This motor resonance may bias children's imitation in successive-models paradigms, as having imitated the first model, during the second model's turn, they cannot help but perform the action they have just performed during the first model's turn. The follow-up investigated whether children's imitation flexibility on a successive-models paradigm was influenced by their motor inhibition abilities and by whether or not they were given the opportunity to imitate each model in turn. This controlled for whether motor inhibition and ideo-motor learning still bias children's imitation in the early pre-school years. It was found that children's inhibitory ability did affect their imitation, but only when they needed to inhibit performing an action they had previously done. When imitating a model involved adding an action, or performing a task for the first time, this was not related to inhibitory ability, suggesting that imitation may involve separate faculties depending on the type of action that is being performed.

Study 4 looked at the effect of inequivalent models on children's imitation in the successive-models paradigm. As mentioned above, studies looking at children's reactions to deviant models have typically used puppets as the deviant model (Rakoczy et al., 2008; Schmidt et al., 2011; Keupp et al., 2013; Keupp et al., 2016). They also tended to include training phases where the puppet was shown to be rather silly (making elementary mistakes on simple tasks) and children were encouraged to correct them. This means there are additional cues, beyond model identity, that suggest one model is correct and the other is incorrect. In study 4 I tested how 3- to 5-year-olds reacted to seeing either the puppet or an adult as the deviant model in the successive-models paradigm. I was interested whether children always prefer to imitate adults or puppets, or whether their preference depends on the type of action being performed by these models (e.g., when one model includes arbitrary actions). Children did indeed prefer to imitate the adult over the puppet, showing that under the age of 5 years children are sensitive to model identity and use this to decide whether or not to imitate a model. Interestingly, model identity also affected children's ability to omit a previously performed action.

In Study 5 I looked at how it would affect children's imitation when different cues (model vs. object) are in conflict. Children saw two models demonstrate different action sequences, but this time the two models used different versions of the same object. It was then varied which model and which object were present when the child was allowed to imitate. In some cases the model was present with their own object and in others they had the object used by the other, not present model. This set-up investigated whether children would prefer to demonstrate the action they had seen the present model perform, or whether they would prefer to demonstrate the action they had seen the object used for. Given that the social function of imitation seems to emerge around age 2 (Jones, 2007; Kim et al., 2015) and becomes more prevalent with age (Yu & Kushnir, 2014; Marsh et al., 2014) it is possible that, as children become older, they will prefer to copy the model, rather than what was done on the object. In study 5 children were more likely to demonstrate the action of the model who was present than the actions performed on the object and this effect was unrelated to age. However, like in adults, the effect was stronger if the object present on the child's turn was that used by the present model. This study suggests that pre-school aged children and adults are sensitive to objects and models as cues guiding their imitation.

Overall the results from Chapter 3 suggest that imitation is not a unitary ability but is affected by distinct factors such as model identity, object affordances, motor experience and inhibitory ability, but not novel labels. Finding no effect of label suggests that in the type of game context used here, imitation fidelity is not primarily determined by action labels. The finding that imitation is related to inhibitory ability fits with accounts such as IMAIL and ASL which stress that imitation uses the same generalist processes involved in other instances of perception and action production. The findings from Study 4 (the Puppet study) and Study 5 (contrasting the effect of the object or the model) also suggest that model presence and model identity can influence lower-level mechanisms of imitation. This further reinforces the idea that imitation is a composite ability which is affected by action production abilities and higher-order cognitive processes.

As mentioned above the evidence from Chapter 3 suggests that imitation can be affected by more complex cognitive factors than just generalist processes of action production. Taking this further, and following previous work on goal-oriented action understanding, Chapter 4 investigated the effect of action goals and context on high-fidelity imitation. As discussed above, whether actions can be related to meaningful goals affects the likelihood of their being copied faithfully (Gardiner, 2014; Elsner & Pfeifer, 2012; Froese & Leavens, 2014). Whilst infants tend not to copy meaningless actions (Jones, 2007) and prefer to copy actions with salient effects (Kim et al., 2015), in the absence of meaningful goals pre-schoolers seem equally likely to copy movements as well as end effects (Mizuguchi et al., 2011). Schachner and Carey (2013) suggest that one reason for this is that as children age they become more exposed to actions where the movement is an end goal in itself. This would for instance be the case for dancing and ritualistic actions (in line with Wilks et al., 2016; Herrmann et al., 2013). Adults infer such movement-based goals for actions demonstrated without context or evident effects (Schachner & Carey, 2013). This is also compatible with the direct-perception hypothesis which argues that actions are represented in terms of their likely goals from an evaluation of the context (Froese & Leavens, 2014).

The aim of Chapter 4 was to determine whether children aged between 3 and 5 years would also interpret actions as having movement-based goals if these were performed without evident external goals. If so then it was predicted that actions would be imitated more faithfully when movement-based goals were inferred. This was what was confirmed in Study 6: pre-schoolers imitated body- and object-directed actions more faithfully when these were performed without context, replicating previous findings (Bekkering et al., 2000). Study 7 extended this finding by seeing whether children's imitation of action sequences was affected by emphasising that the action sequences had two distinct, unrelated external goals, or a specific movement which led to an external goal. Replicating the results from Study 6 pre-schoolers imitated actions more faithfully when they could be related to a movement-based goal than when they could be related to distinct external goals. In comparing the results from Studies 6 and 7, children were shown to imitate actions more faithfully when movement-based goals could be inferred, even when the amount of actions and objects present was the same. This suggests that by age 3 years, children's imitation of actions is indeed affected by the goals that can be associated with those actions, and that pre-schoolers, like adults (Schachner & Carey, 2013), readily interpret actions performed without contexts as having movement-based goals.

The findings from the above chapters will be discussed in the concluding chapter 5. I will argue that from the findings in this thesis and from previous research, imitation does not seem to be a unitary ability, but is modulated by a number of general action production abilities. Thus children will only be able to imitate an action faithfully if they have the *potential* to produce that action. However high-fidelity imitation will occur if children can infer a movement-based goal to the model's actions. This shows that pre-schoolers' evaluations of action goals also affect their imitation of those actions. These evaluations change throughout childhood, as children become more susceptible to social cues and will be more likely to imitate faithfully with age. Imitation is affected by children's interpretations of the action in question, and from pre-school age onwards children use their action understanding capabilities to infer likely goals about actions which therefore modulate their copying behaviour. Imitation can therefore be affected by higher-order cognitive processes in a top-down manner, like perception (as when expectancies bias one's perceptions). Overall the evidence suggests that, as posited by generalist accounts of imitation, there is not one simple imitative skill but rather a multitude of abilities subserving the ability to replicate another's actions. Finally I will highlight directions for future research and I conclude by showing that imitation is affected both by what the child *can* do, and what they think they *should* do.

CHAPTER 2

INTRODUCTION

Imitation is a particularly efficient means for children to acquire new skills. By copying other people's actions children learn how to use new tools (e.g., Whiten & Flynn, 2010) and thereby avoid costly trial-and-error learning (Gardiner, Bjorklund, Greif, & Gray, 2012; Gardiner, 2014). Imitation also helps acquire relevant cultural knowledge (Gergely & Csibra, 2005) and is a way of communicating and socializing with others (Nadel & Fontaine, 1989; Nadel, 2002; Over & Carpenter, 2012). As such imitation can serve multiple functions, such as knowledge acquisition and affiliation with a person or a social group.

The type of function may be defined through the context in which an action is presented and can affect the way children copy: for example, 2-year-olds are more likely to copy non-functional actions (e.g., removing a latch from door A before opening door B) in a social context ('Copy-Me') than in a learning context ('Find-the-piece', Yu & Kushnir, 2014). Similarly in some contexts children imitate selectively (e.g. they copy intentional but not accidental actions, Carpenter, Akhtar & Tomasello, 1998; Gardiner, Greif, & Bjorklund, 2011; Hoicka & Gattis, 2008; see emulation, Wood, 1989; Tomasello, 1990) whereas in other contexts they imitate overly faithfully (e.g. they copy actions non-functional to the goal, Horner & Whiten, 2005; Nagell, Olguin & Tomasello, 1993; see over-imitation, Lyons, Young, & Keil, 2007).

As the function of imitation affects the way children copy, a crucial question is whether this changes throughout childhood. There are a number of changes in imitation with age. Children under the age of 2 years prefer to imitate actions on objects that lead to obvious consequences (e.g. tapping a hammer on a peg to put it through a hole) than body movements that do not have salient effects (i.e. arbitrary actions; Christie & Slaughter, 2009; Kim et al., 2015). This is presumably because salient action consequences can be associated easily with specific movements (Paulus, 2014). During the second year of life, however, infants spontaneously begin to mimic others during play (Nadel & Fontaine, 1989), and children's imitation of arbitrary actions without salient external effects also increases during their second year. Imitation of arbitrary actions even increases beyond infancy, as older children and adults copy arbitrary actions more faithfully than younger toddlers (McGuigan, Makinson & Whiten, 2011).

As children age they also become more likely to display high-fidelity imitation in the absence of instructions to do so (Moraru, Gomez & McGuigan, 2016; Whiten, Allan, Devlin, Kseib, Raw & McGuigan. 2016; Yu & Kushnir, 2014). This could be taken as evidence that the social function of imitation becomes more important for children with age: to copy what the model does faithfully without being told to do so could indicate that the learner wants to affiliate with the model, and, as high-fidelity imitation increases with age, older children may imitate for social reasons more than younger children.

A useful way of assessing how children interpret a model's actions (and subsequently imitate) has been to analyse children's imitation of successive models (e.g. Rakoczy, Warneken & Tomasello, 2008). In this paradigm, children observe two models, Model 1 (M1) and Model 2 (M2) who demonstrate slightly different ways of performing the same task (which is referred to by the same label, for example "daxing"). Children's imitation of the two models gives some indication of the way they interpret the actions of the models and thus how they feel they should imitate. For example, children may interpret the first action sequence as the correct way to perform the task and therefore not imitate the second model at all. This would indicate that children view one action sequence as the "correct" way of performing the task. They may in contrast show no preference for either action sequence and instead focus on copying the actions of whichever model is present, showing a social goal of affiliation with their counterpart.

Up until now successive-models paradigms have mostly been used to look at the imitation of pre-school aged children (e.g. Keupp, Behne & Rakoczy, 2013; Nielsen & Blank, 2011; Rakoczy, Warneken & Tomasello, 2008; Rakoczy, Brosche, Warneken & Tomasello, 2009; Rakoczy, Hamann, Warneken & Tomasello, 2010; Schmidt, Rakoczy & Tomasello, 2011, 2012; Schleihauf, Graetz, Pauen & Hoehl, 2017). The task has been used to clarify the function of imitation in pre-schoolers, but it remains to be seen how children react to multiple models at later stages in childhood.

The present study set out to collect data on a large age range to measure children's imitation between the ages of 2 to 12 years using a successive-models paradigm. The design of the task was similar to that used by Nielsen and Blank (2011): one model demonstrated a functional action (F), such as opening a lid to move a toy, and another model demonstrated an arbitrary action[2] (A; see Nielsen, Kapitány & Elkins, 2015)—prior to the functional action (F)—that had no bearing on the goal (e.g., brushing the lid in circular motions). Hence, one model showed only action F, whereas the other model demonstrated action A prior to action F.

Unlike in Nielsen and Blank's study, the two models acted in each other's absence (i.e., one model always left the room) so that children would not encode the situation as one adult teaching the other, or interpret their non-interference in the other adult's turn as tacit consent that the task could be done either way. Additionally, and again unlike Nielsen and Blank, both models labelled their actions in the same way (e.g., "Lopping"). It was important to establish the same context in which the two models were presenting their actions, because children, like adults, assume that objects exist for a purpose (Kelemen, 1999). But because objects can have different *affordances*, and as such serve a different function for different people, without using the same context, this would resolve the ambiguity of what to do in a model's presence (see also Rakoczy et al., 2008). Additionally, children were asked to do the task (e.g., to lopp) after each demonstration: Nielsen & Blank, in contrast, had children only watch the models. If children only observe the models, they may not be as involved in the task: having children imitate each model in turn thus means that children will have previous experience of "lopping" when they see M2 attempt to do it in a different way. Also, the first model came back again and—without demonstrating any further actions—asked the child to do the task a third time thus establishing which of the modelled actions the child would reproduce.

This design will provide insight into how children interpret the actions of the two models, and thus reveal the function they attribute to imitation in this setting. If children conceive of the task as a learning situation, where the goal is to learn how to produce the effect of the functional action, then they should show low imitation of the arbitrary action, especially once they have seen the task performed without it. In contrast if they conceive of the task primarily in a social way, then they should copy both models relatively faithfully regardless of the actions these models use. Due to age differences in previous studies, particularly the increase in high-fidelity imitation with

[2] The term "arbitrary" rather than non-functional is used because in some of the tasks the apparatus was transparent and in others the apparatus was opaque. In the latter cases the non-functionality of the action remained unclear, therefore arbitrary better represents the status of these actions for the children.

age (Hilbrink, Sakkalou, Ellis-Davies, Fowler & Gattis, 2013; Marsh et al., 2014; McGuigan, et al., 2011; Nielsen, 2006; Nielsen & Tomaselli, 2010; Yu & Kushnir, 2014) it is predicted that imitation fidelity for both models will increase with age.

It was also manipulated how easily the arbitrary action A could be seen to be non-functional. Horner and Whiten (2005) observed that, unlike chimpanzees, 3- to 5-year-old children copied non-functional actions equally regardless of whether they could see their effects or not (but not younger children – see McGuigan & Whiten, 2009). In this study there were some tasks where the arbitrary action A could clearly be seen to have no effect on the goal (transparent tasks), and other tasks where its effect was unclear (opaque tasks). If children are influenced by the effectiveness of the actions to produce a salient effect (e.g. Lyons et al., 2007) then they should imitate arbitrary actions less frequently in the transparent tasks. In contrast, if children's imitation is socially motivated, whether or not they see the effect of the arbitrary action A, should not matter.

METHODS

Participants. The study recruited 105 children from Scottish schools, playgroups and nurseries. Two children were excluded for uncooperativeness. The final sample consisted of 103 children (M_{age} = 94 months, *SD* = 37 months, age ranging from 26 months to 155 months, 50 male). The sample was divided into six groups: 17 2- to 3-year-olds (*M* = 39 months, *SD* = 5 months, 8 male), 17 4- to 5-year-olds (*M* = 61 months, *SD* = 6 months, 9 male), 17 6- to 7-year-olds (*M* = 85 months, *SD* = 6 months, 9 male), 17 8- to 9-year-olds, (*M* = 107 months, *SD* = 7 months, 8 male), 18 10- to 11-year-olds (*M* = 128 months, *SD* = 5 months, 6 male), and 17 11- to 12-year-olds (*M* = 143 months, *SD* = 5 months, 10 male). All children were typically developing for their age. At all locations parental consent was granted prior to testing, and ethical approval was provided by the University's Ethics Committee.

Design. Each child observed four tasks (Lopping, Trepping, Chokking and Mooshing). The order of the tasks was counterbalanced in a Latin Square Design. In each task children saw two models, one who demonstrated only the functional action (F) and the other one who demonstrated the arbitrary action (A) prior to the functional action (F). Each child saw two tasks where the first model (M1) demonstrated F and the second model (M2) demonstrated AF (F_{first} condition), and two tasks in the reverse order

(AF_{first} condition). In both conditions children saw one transparent task and one opaque task, either in a transparent-opaque-transparent-opaque order or an opaque-transparent-opaque-transparent order. Different pairs of experimenters collected the data, but all experimenters were white females in their early twenties. Experimenter identity was counterbalanced.

Materials and Procedure**.** Four apparatuses were custom-made for this study (see Table 1).

Table 1. Materials and actions used for the games in Study 1.

Label - Transparency	*Materials*	*Functional Action (F)*	*Arbitrary Action (A)*
Lopping / Transparent 	A plastic food container, a small dog plush toy, a small wicker basket and a toothbrush.	Opening the container lid with the goal of placing the dog toy in the basket	Brushing the top of the container with the toothbrush
Mooshing / Transparent 	A CD case containing marbles, a small golden ring and a plastic container	Opening the CD case, with the goal of moving a marble into the plastic container	Removing a ring from the centre of the CD case
Trapping - Opaque 	A cardboard box, a small caterpillar toy, a plastic container and some marbles in a green cup	Lifting the caterpillar out of the side of a box with the goal of moving it to the container	Placing a marble in the top hole of the box (into a separate hidden compartment)
Chokking – Opaque 	A big plastic jug, a plastic wand, some marbles in a cup and an additional plastic cup	Placing marbles in the jug with the goal of pouring them into an empty cup	Using the wand to stir the marbles in the jug

Note. Portrayed are the four different games, their names and transparency as well as the respective functional and arbitrary actions.

Children were tested individually in a separate room. At the beginning M1 and M2 introduced themselves, upon which M2 left the room (M2 was still able to see M1 and the child from their position outside the room as the door was left open, however the child was always placed with their back to the door). M1 and the child sat down at a table, with the child opposite M1 and the materials hidden next to M1 in a box. In the meantime M1 demonstrated the first action sequence, either F or AF, using the novel label for that task “OK, we are going to play a game: this game is called [name of task] and this is how it goes”.

F_{first} condition. M1 demonstrated the functional action (F) and said “That is how you [name of task]”. They reset the apparatus and performed the task a second time and announced “OK, that is how you [name of task]”. M1 reset the apparatus again and said “OK, now it’s your go to [name of task].” The child was then allowed to perform the action and their behavioural and verbal responses were recorded.

After the child responded M1 reset the apparatus and left the room, upon which M2 entered the room and sat where M1 sat before saying “Now I’m going to [name of task], watch carefully”. M2 then performed both the arbitrary action (A) and the functional action (F), stating “This is how you [name of task]”. They reset the apparatus and performed the actions again, concluding with “That is how you [name of task].” M2 reset the apparatus and announced “Now it’s your go to [name of task]”. The child was allowed to respond and M2 recorded their responses.

M2 then reset the devices and left the room. M1 returned, sat down and said “You know how to [name of task]. Can you do it one more time?” This time M1 did not demonstrate any actions. The child’s final response was recorded. Then M1 said “Now we’re going to play a new game”. The apparatus was removed and the materials for the next task were set up.

AF_{first} condition. The procedure and script were identical to the F_{first} condition, except that M1 demonstrated the action sequence containing both arbitrary (A) and functional (F) actions, whereas M2 demonstrated the functional action (F) only.

If a child did not respond during their turn then the model waited 5 seconds before saying “go on, it’s your turn, you can have a go”. If the child still did not respond the model said “I will show you the game again, OK?” before demonstrating the solution a third time and resetting the apparatus. This occurred once for two of the 2- to 3-year-olds.

Scoring. Children gave 12 responses overall (three for each of the four tasks) which were recorded during the testing sessions. For reliability purposes, both M1 and M2 recorded the child’s responses. Both models kept an individual scoring sheet d – M1 had theirs next to the table for data collection and M2 had theirs next to their waiting spot outside of the room (from which they could see the child). Both models recorded children's responses to M1, M2 and M1rep and then were able to compare their notes after each child. There were no disagreements between the models.

Children received one point if they demonstrated the action used by the model present. By omitting part or all of that model's action sequence or doing something unrelated the child was considered not to have imitated and received a score of 0. To identify how often children copied each model an overall score for each model was computed. The M1 score thereby refers to how often children copied the first model across all four tasks ($M1_{max}$= 4). The M2 score refers to how often children copied the second model across the four tasks ($M2_{max}$= 4), and the $M1_{rep}$ score refers to how often children demonstrated M1's action upon her return ($Mrep_{max}$= 4).

To distinguish between instances when children omitted arbitrary actions versus doing something incomplete or unrelated, each child's individual response patterns were identified. This allowed determining whether children copy M1 on all three trials (M1-M1-M1 pattern), whether they switch between M1 and M2 consistently (M1-M2-M1 pattern) or whether they prefer copying M2's actions once they have seen them (M1-M2-M2 pattern).

As previous successive-models paradigms like the one used here have been used to assess children's normative understanding (Keupp, Behne & Rakoczy, 2013) a protest score was calculated for each child. Based on Keupp et al. (2013) different types of protest were coded: If children used explicit normative language to rebuke the adult ("No, you must do it like this") they were deemed to have displayed normative protest and received a score of 3. If they told the model to do/not do something in a certain way it was coded as imperative protest and received a score of 2. If children used commands ("No!") or tried to correct the adult physically this was coded as a hint of protest and was given a score of 1. No protest received a score of 0.

RESULTS

Preliminary analysis. There was no difference for the imitation scores M1, M2, and $M1_{rep}$ between the four different tasks, Cochran's χ^2 all *ps* > .25. The sum imitation scores M1, M2 and $M1_{rep}$ were also similar for boys and girls, t-tests all *ps* > .43. Children did not preferentially imitate either of the experimenters in any of the pairs for

M1, M2 or $M1_{rep}$ scores, all *p*s > .5. As none of these analyses revealed significant effects, data was collapsed across these variables and not analysed further.

Imitation scores. A mixed factorial repeated-measures ANOVA was conducted on the imitation scores with model (M1, M2, $M1_{rep}$) and transparency (transparent vs opaque) as within subject factors and condition order (F_{first} or AF_{first}) and age-groups (6 levels) as between subject factors. There was a main effect of model, $F(2, 182) = 54.83$, $p < .001$, partial $\eta^2=.38$, such that M1 was copied without deviation ($M = 2.0$, $SE = .0$). In contrast, M2 ($M = 1.45$, $SE = .04$) and $M1_{rep}$ ($M = 1.51$, $SE = .06$) were copied at equal rates (Within-Subjects contrast, $F(1, 91) = .46$, $p = .46$), but less faithfully than M1, $F(1, 91) = 288.09$, $p < .001$. Neither transparency ($F(1, 91) = .73$, $p = .40$, partial $\eta^2=.008$) nor order of conditions, F_{first} or $AF_{first,}$ ($F(1, 91) = .09$, $p = .76$, partial $\eta^2=.001$) affected imitation scores.

As predicted, age affected imitation scores to a great extent, $F(5, 91) = 27.64$, $p < .001$, $\eta^2=.60$. With increasing age children copied more faithfully overall, $r = .75$, $p < .001$. Bonferroni corrections were applied to LSD post-hoc tests to control for the increased number of comparisons between the 6 age groups: the adjusted significant *p* value was .0033 (given that there were six age groups and fifteen comparisons to be made between them). The post-hoc tests revealed that the 2- to 3-year-olds, 4- to 5-year-olds and 6- to 7-year-olds had similar imitation scores overall (highest *Mdif* = -.218, *SE* = .072, *p* = .046) but they were all less accurate imitators than the 10- to 11-year-olds and the 11- to 12-year-olds (smallest *Mdiff* = .366, *SE* = .069, *p* > .001). The 8- to 9-year-olds had significantly higher imitation scores than the 2- to 3-year-olds and 4- to 5-year-olds (smallest *Mdiff* = .363, *SE* = .072, *p* > .001), but the 6- to 7-year-olds and 8- to 9-year-olds did not have significantly different imitation scores, *p* = .654. The 8- to 9-year-olds had significantly lower imitation scores than the 11- to 12-year-olds (*Mdif*f = -.276, *SE* = .071, *p* = .0027) but not the 10- to 11-year-olds, *p* = .031. Finally the 10- to 11-year-olds and 11- to 12-year-olds did not imitate significantly differently from one another, *p* = 1. Figure 1 displays the sum imitation scores for M1, M2 and $M1_{rep}$ split up for the 6 age groups. The results from both the figure and the post-hoc analyses suggest that there were several distinct steps in children's imitation: M2 imitation scores were not as high as M1 scores until after age 5, and M1rep scores only reached ceiling levels for children above 9 years.

While the effect of condition order (F_{first} or AF_{first}) was not significant in the analysis, Table 2 displays the imitation scores for the F_{First} and AF_{First} conditions for the 6 different age groups to clarify the data in more detail. As can be seen, the only apparent difference between the F_{First} and AF_{First} condition was for the 4- to 5-year-olds. In this age group children imitated M2 more in the F_{First} condition than in the AF_{First} condition, and also imitated M1rep less in the F_{First} condition than in the AF_{First} condition. This means that the 4- to 5-year-olds preferred to copy the arbitrary action once they had seen it, leading to them copying either M1's actions throughout in the AF_{First} condition or switching to M2's action in the F_{First} condition. However the conditions were not significantly different in the main analysis, and no other age groups had different scores between the two conditions.

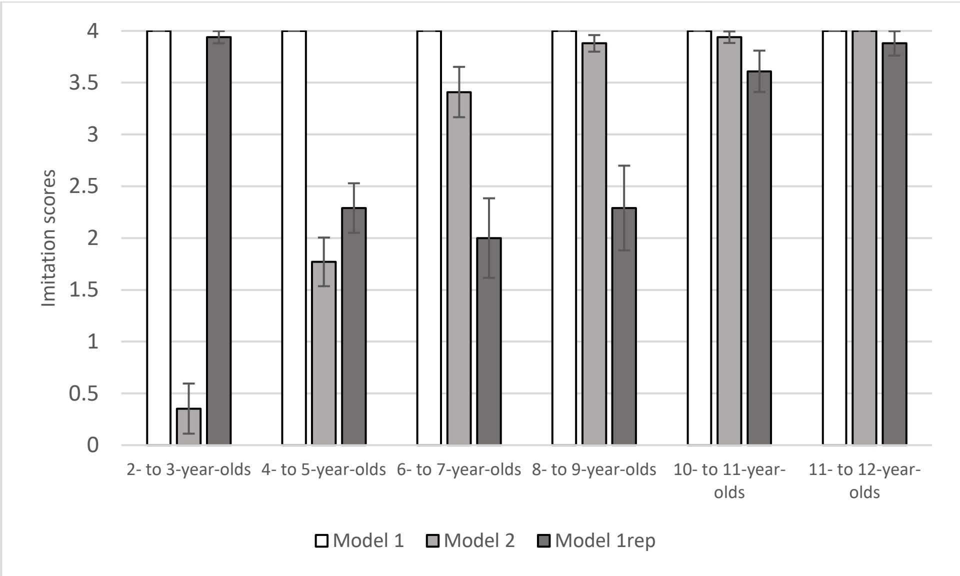


Figure 1. Mean M1, M2 and $M1_{rep}$ imitation scores across all tasks between age groups. Bars indicate standard errors.

	Model 1		Model 2		Model 1rep	
	F First	AF First	F First	AF First	F First	AF First
2- to 3-year-olds	2 (0)	2 (0)	.24 (.54)	.12 (.49)	1.94 (.24)	2 (0)
4- to 5-year-olds	2 (0)	2 (0)	1.65 (.79)	.12 (.49)	.41 (.8)	1.88 (.49)
6- to 7-year-olds	2 (0)	2 (0)	1.77 (56)	1.71 (.59)	.82 (.95)	.88 (.99)
8- to 9-year-olds	2 (0)	2 (0)	1.94 (.24)	1.94 (.24)	1 (.91)	1.12 (.93)
10- to 11-year-olds	2 (0)	2 (0)	2 (0)	1.94 (.24)	1.84 (.5)	1.78 (.55)
11- to 12-year-olds	2 (0)	2 (0)	2 (0)	2 (0)	1.88 (.49)	2 (0)

Table 2. Mean M1, M2 and $M1_{rep}$ imitation scores for all six age groups in both the F_{First} and AF_{First} conditions. Figures in brackets are standard errors.

Age also interacted with the model scores M1, M2, $M1_{rep}$, $F(10, 182) = 26.87$, $p < .001$, partial η^2=.60. M1 was imitated perfectly by children of all ages. However M2 and $M1_{rep}$ imitation scores varied with age. A simple linear regression confirmed that M2 imitation scores increased with age, $F(1, 101) = 207.56$, $p < .001$ with an R^2 of .67, thereby increasing imitation accuracy by .035 points for every month. Therefore as children aged they became more likely to imitate M2. For $M1_{rep}$ scores the data appeared u-shaped, so a hierarchical multiple regression, using age in months in Block 1 and age in months squared in Block 2 was conducted. Age in months did not explain any of the variance, $F(1, 101) = 1.17$, $p = .28$. However, when age in months squared was added as a predictor ($b = 3.013$, $p < .001$) the regression equation was significant, $R^2 = .311$, $F(1, 100) = 22.56$, $p < .001$.This confirms that the youngest children reproduced M1's actions more precisely on her return than did pre-school aged children, but imitation fidelity for $M1_{rep}$ increased again in pre-adolescence.

Response Pattern. If a child demonstrated M1's actions on all three trials within a task, it was coded as M1-M1-M1. If a child demonstrated what M1 did on the first round, but then demonstrated M2's actions for the following two rounds it was coded as M1-M2-M2. Finally, children who demonstrated actions of whichever model was present in the room were coded as M1-M2-M1. Figure 2 displays the occurrences of the different response patterns in each age group. Overall children replicated M1's actions on all three turns (M1-M1-M1 pattern) 92 times (28%). This pattern was only shown by 2- to 3-year-olds (n = 60) and 4- to 5-year-olds (n = 32). The model-dependent imitation

(M1-M2-M1 pattern) was shown 174 times (52%), and was mainly present from 6 years onwards with increasing frequency (2- to 3-year-olds: n = 4; 6- to 7-year-olds: n = 18; 8- to 9-year-olds: n = 28; 10- to 11-year-olds: n = 58; 11- to 12-year-olds: n = 66). Finally, copying M1 but then switching to M2 (M1-M2-M2 pattern) was observed 66 times (20%). It was present from 4 years onwards with decreasing frequency (4- to 5-year-olds: n = 26; 6- to 7-year-olds: n = 20; 8- to 9-year-olds: n = 16; 10- to 11-year-olds: n = 2; 11- to 12-year-olds: n = 2). The age-groups differed in frequency for all three patterns (M1M1M1: Kruskal-Wallis χ^2 (6) = 85.67, p < .001; M1M2M2: Kruskal-Wallis χ^2 (5) = 33.04, p < .001; M1M2M1: Kruskal-Wallis χ^2 (5) = 78.30, p < .001). As children got older, the M1M1M1 pattern decreased, r = -.812, p < .001, while the M1M2M1 pattern increased in frequency, r = .744, p < .001. The M1M2M1 pattern also decreased with age, but marginally significantly, r = -.192, p = .052.

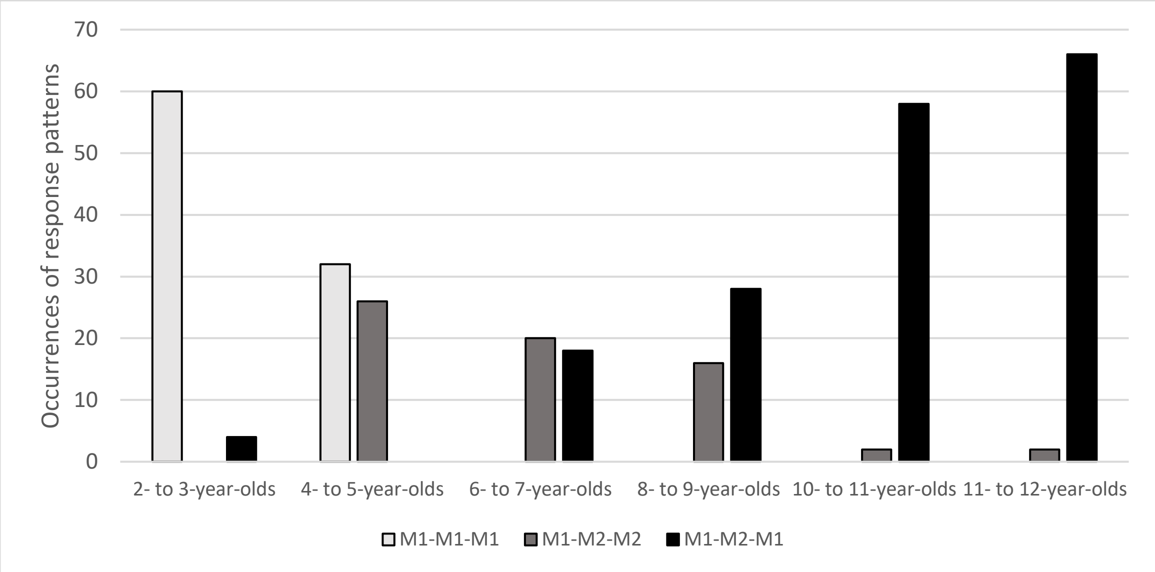


Figure 2. Frequencies for different response patterns occurring in each age group.

Protest. Explicit protest was rare, with only nine incidents of normative protest (e.g. “No, you need to do this”). There were, however, 15 instances of imperative protest (where the child told the adult to do something/not do something) and 43 instances of hints of protest (where the child only said “No!” or corrected the adult physically). Figure 3 displays the occurrences of different types of protest within each age group. Protest occurred exclusively on M2 trials. Six instances of normative protest occurred within the 2- to 3-year-olds and 3 occurred for the 4- to 5-year-olds. Six instances of imperative protest occurred for the 2- to 3-year-olds, 7 for the 4- to 5-year-olds and two occurred for the 10- to 11-year-olds.

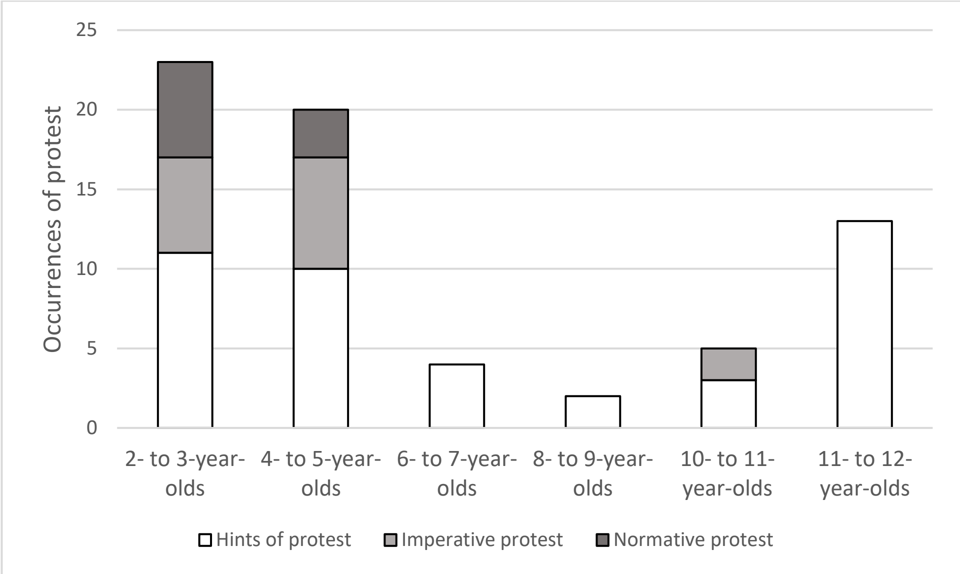


Figure 3. Frequencies of protest occurrences within each age group.

The protest scores for the F_{first} tasks were subtracted from the protest scores for the AF_{first} tasks. This produced a protest difference score for each participant: if it was positive then the participant protested more when M2 omitted an action. If it was negative then the child protested more when M2 added an action. The 2- to 3-year-olds (*M* = .41, *S.D.* = 1.37), the 6- to 7-year-olds (*M* = -.12, *S.D.* = .33), the 8- to 9-year-olds (M = 0, *S.D.* = 35), the 10- to 11-year-olds (*M* = .28, *S.D.* = .75) and the 11- to 12-year-olds (*M* = .06, *S.D.* = .9) responded very similarly in the two conditions, as indicated by a one-sample t-test with the chance value set at 0, all *p*s > .13. In contrast, 4- to 5-year-olds protested significantly more when M2 omitted an action than when she added an action (*M* = .88, *S.D.* = 1.2), $t(16) = 2.99$, $p = .009$, which is consistent with the finding that they preferred to imitate M2 when she added an action.

DISCUSSION

Study 1 investigated how children's imitation of successive models changed with age. Two adults demonstrated the same functional action (e.g., opening a lid to move a toy), but one model additionally demonstrated an arbitrary action (e.g., brushing the lid in circular motions). In some conditions the arbitrariness of the added action was transparent, while in others it was not.

The results show that the youngest group, aged 26 to 47 months, copied whatever M1 did without deviating from this solution even after having observed a different way of attempting the task by another model. This will be referred to as *perseverative imitation*, as children persevered with the actions demonstrated by M1 rather than switching to M2's actions. In contrast, children aged 4 to 5 years copied the second model when she added an arbitrary action, but not when she omitted it. This meant that they always preferred the longer solution once they had seen it and protested against omitting an action. The 6- to 7-year-olds and the 8- to 9-year-olds were more likely to copy the second model, compared with the younger age groups, regardless of the condition (i.e., whether the model added or omitted an action), but they were equally likely to demonstrate M1's or M2's actions upon M1's return ($M1_{rep}$). In contrast, the oldest children, aged from 10 to 12 years, imitated whoever was present in the room, displaying what will be termed *model-dependent imitation*. They thereby obtained near ceiling imitation scores for all trials, making them so-called "super-imitators" (Custance, Prato-Previde, Spiezio, Rigamonti, & Poli, 2006). Overall, imitation fidelity increased with age, a finding in line with previous studies (e.g. Marsh et al., 2014; McGuigan et al., 2011, Nielsen, 2006).

A study supporting these findings in pre-schoolers has recently been published by Schleihauf, Graetz, Pauen and Hoehl (2017, Experiment 1) who investigated imitation in 5-year-olds. In a similar design to the present study, children observed two models demonstrate different ways of retrieving a marble from an apparatus and were given two opportunities to retrieve these marbles, once after each model's turn. Unlike the current study, however, models were not present for the children's turns and children were not given a third turn. Overall Schleihauf et al. found that once children had imitated a model's arbitrary actions whilst obtaining a marble, they did not subsequently omit this arbitrary solution even when they saw the other model do so. This finding mirrors the results for the AF_{first} condition in the current study, in which the 4- and 5-year-olds continued using arbitrary actions even after having observed a model use the functional action only. Also mirroring the present results, Schleihauf et al.'s Experiment 2a had M2 demonstrate the arbitrary action (i.e., F_{first} condition) and children were marginally significantly more likely to perform arbitrary actions once they had observed them (this difference became significant when data were combined with Experiment 2b).

The findings from the current Study 1 can be examined using predictions made by existing theories of imitation. Firstly, consider the automatic causal encoding theory (Lyons et al., 2007). If children copy arbitrary actions faithfully because they assume every intentional action is causally relevant to achieve a goal then they should only copy the functional action once they have seen it done alone. No age groups exhibited this response, indicating that a distorted causal belief does not seem to be directing children's imitation in this set-up. This is further supported by the absence of differences between the opaque and transparent tasks. Previously some studies did report a difference between transparent and opaque set-ups (e.g., Lyons et al., 2007; Gardiner, 2014), but other studies have not (e.g., Horner & Whiten, 2005; Kenward et al., 2011; McGuigan & Whiten, 2009; McGuigan et al., 2007). In the present study the tasks were described as games: in such cases causality is not always the most important concern, and an element of arbitrariness is always present in games and conventions (Wilks et al., 2016). Given that the tasks in Study 1 were described as games, children may not have focussed on achieving the effect in the most efficient way possible.

Another account of children's imitation emphasises the importance of normativity and conventions (Rakoczy et al., 2008; Wilks et al., 2016). Previously successive-models paradigms have often shown that children will not imitate a deviant model who attempts to perform a known task in a novel way – pre-schoolers will perform the task in the way performed by the first model (an adult), and protest against a puppet who does the task in a different way (Rakoczy et al., 2008; Keupp et al., 2013). The current Study 1 extended these findings by examining how children imitated successive models who were both adults. A preference for M1's actions was observed in pre-school aged children, as they imitated M1's actions more than M2's actions. In particular the very youngest children, aged between two and 3 years, imitated M1 on all three turns. These children may have interpreted the actions of M1 as normative, the "correct" way of performing the task. The vast majority of incidents of protest towards M2 also occurred for children under 5 years, which according to Rakoczy and colleagues suggests that these children viewed M2's actions as "incorrect", implying a normative understanding of the task. It could therefore be argued that children under the age of 5, and particularly the 2- to 3-year-olds, viewed M1's actions as normative, and imitated M1 more than M2 because M1 was considered to have demonstrated the "correct" way of playing the game.

A caveat with this interpretation however is that children's rule understanding is flexible enough to produce different responses on the same stimuli by this age: Zelazo and Frye (1998) presented evidence that 3-year-olds can use two rules to sort cards provided these rules are not incompatible (e.g. "if the card is red, it goes in this pile, if it is blue, it goes in this pile"). In line with this, 3-year-olds protest against a puppet's mistakes when these mistakes are made in a context where the rules apply ("This is how to dax"), but not in the context in which these rules do not apply (Rakoczy et al., 2009). This shows that by age 3 children may use rules like "if in context A, you do this; if not in context A, you don't have to do this". In the current study, 3-year-olds could therefore have been able to use the rule, for example, "if M1 is present, do F; If M2 is present, do AF". This would seem especially likely as, unlike previous successive-models studies (Rakoczy et al., 2008, 2009; Keupp et al., 2013), the two models in Study 1 were of equal status (i.e. two adults, neither of whom was presented as making silly mistakes). Children would thus have no reason to assume that one model was more likely to be correct than the other. Such an interpretation should have led children to copy M1 and M2 faithfully. As children under 5 years did not present such normative flexibility, it seems less likely that their imitation of M1 over M2 was due to rigid normative understanding.

Given that children's low imitation of M2 was unlikely to be due to a rigid understanding of norms, the role of other factors should be considered. One possibility is that children's imitation on this task may have been constrained by the fact that the two models referred to their actions with the same novel label (e.g. "lopping"). Brandl et al. (2015) argued that one factor driving children's protest towards deviant models in successive-models tasks is because the two models typically use the same label to refer to their actions, and children may dislike this. More specifically children may protest against the fact that M2 says they will do some action labelled F, and then perform a different action AF. This would not necessarily require an understanding of normativity, as protest towards a deviant model can be about their deviance from a statistical expectancy or from a constitutive rule, without entailing the punitive action that follows breaking social norms (Brinck, 2015). Children are sensitive to the labels and contexts models use for describing their actions and modulate their protest accordingly: pre-schoolers protest more against a puppet's deviant actions if the puppet attempts their new action in the context associated with a known action than when the puppet performs deviant actions in a neutral context (Rakoczy, Brosche, Warneken & Tomasello, 2009). In the present study the two models referred to their actions by the same label and used the same materials, which may have made the young pre-schoolers less likely to imitate M2's actions.

There is another interpretation that can explain the imitation pattern for the children under 5 years. Rather than being inflexible in their understanding of labels, the youngest children in Study 1 may have simply found it difficult to imitate the two models' actions on the same task. Imitation is driven by one's own action experience: whether children will imitate depends on their experience performing the action in question (Hunnius & Bekkering, 2014; Paulus, Hunnius, Vissers & Bekkering, 2011; Gampe, Prinz & Daum, 2015). The IMAIL and ASL accounts of imitation stress that imitation is driven by action experience, which forms associations between an observed effect and the movements producing that effect (Catmur, Walsh & Heyes, 2009; Paulus, 2014). Having experience of doing an action oneself will make it easier to imitate that action (Gampe et al., 2015). In Study 1, children observed M1 and then imitated M1's actions. Their lack of imitation of M2 may therefore have been due to the fact that they could not inhibit performing M1's actions. This would also explain why imitation of M2 increased between the ages of 2 and 5 years, as motor inhibition abilities improve during this period (Carlson, 2005). Such an explanation would be predicted by generalist accounts of imitation which stress that imitation is subserved by the general processes of action control, rather than specialised matching mechanisms (Brass & Heyes, 2005; Paulus, 2014). Given that the youngest children's other cognitive abilities were still developing, they could not override previous action experience which led to poor imitation of M2, particularly when this meant that one had to omit the arbitrary action. The design of Study 1 does not suggest which explanation (inflexible use of labels vs poor motor inhibition) underlies the pre-schoolers' poor imitation of M2. This will be one of the research questions of Chapter 3.

A third theory of high-fidelity imitation in children is the affiliation account: this theory suggests that children focus on copying the present model, regardless of the type of action that is performed by that model. The aim is to match the movements of the model faithfully, to affiliate with them (Nielsen & Blank, 2011; Over & Carpenter, 2012; 2013). In the current study children above the age of 6 years copied both M1 and

M2 faithfully, regardless of what actions the models performed, but were at chance as to who to copy on $M1_{rep}$. In contrast by the age of 10 years children faithfully imitated whichever model was present, displaying model-dependent imitation. The presence of M1 did not encourage faithful imitation of M1 on $M1_{rep}$ for younger children. Marsh et al. (2014) argue that the drive to copy a model's actions for social reasons (i.e. to affiliate with the model rather than to cause an effect) increases between the ages of 5 and 8 years. In their study children aged between 5 and 8 years replicated clearly arbitrary actions and grew more likely to do so with age: the authors suggest that this is evidence that by mid to late childhood children imitate to affiliate with the model, and this tendency increases with age. This explanation would also predict the findings from Study 1: as children aged they focussed more on imitating the present model rather than on performing the task in a certain way.

One question is why children become more likely to copy for social reasons as they get older. Children may become more sensitive to pressure to conform: in ambiguous situations (where there is no clear indication that one solution is better than another) children's conformity increases between the ages of three and 10 years (Haun, van Leuwen & Edelson, 2013). The game context in the present study is an example of such an ambiguous situation. Children had no reason to prefer one of the model's actions, as it was not made clear if one solution was better than another. Children's growing experience with social situations where they need to copy other people may explain why the assumption that they need to faithfully imitate each model becomes more automatic with age. After the age of 5 years children are in full-time education where they are encouraged to learn from teachers and to interact with peers – they are also sensitive to the threat of social exclusion and conform to majority judgments in public at this age (Haun & Tomasello, 2011; Over & Carpenter, 2009). Learning to imitate the actions of the model faithfully may become second-nature with age, as children become more exposed to situations where conformity is encouraged or where non-conformity is punished by social exclusion. Children may become more likely to automatically assume that they should copy the present model with age: this would explain why high-fidelity imitation increases throughout childhood and even into adulthood (McGuigan et al., 2011; Whiten et al., 2016). This would also explain why high-fidelity imitation increases with age even when children are not explicitly told to imitate the present model faithfully (Moraru et al., 2016).

It can be pointed out that some of the 8-year-olds, approached after the study, said “I liked that game – you just had to copy each one, right?”, indicating that the goal of copying each model was spontaneously inferred by children above the age of 8 years. Children under 6 years did not infer the social goal of copying the present model, and instead focussed on reproducing the task a certain way. Given that there were no real cues as to one solution being more appropriate than the other (e.g. no reassurance from a third party, no negative consequences from either solution), the pre-schoolers were often at chance as to which solution to use after they had seen both. Wood, Kendal & Flynn (2013b) observed that once 5-year-olds had seen two solutions of performing the same task, they were at chance as to using either solution. This matches the data from the current findings in that children under 6 years did not show a preference for demonstrating M1 or M2’s actions on $M1_{rep}$. The social goal of copying the present model was inferred more by the older children than the younger children, suggesting that matching the movements of the present model becomes a more prevalent goal for children throughout childhood, particularly above the age of 6 years. An important point to note is that, if imitation fidelity for the successive models was indeed related to growing action control capabilities under the age of 6 years, and to growing social motivation above the age of 6 years, then this would suggest that imitation is a composite ability. Rather than a single, specialised imitative ability, children’s imitation is driven by their own action control capabilities and by their growing social experience (amongst other things), meaning that multiple abilities determine imitative fidelity (Subiaul, Patterson, Schilder, Renner & Barr, 2014). The type of goal children infer from social learning situations will also determine the way they imitate, and this process of goal inference changes with age. The following chapters will examine how multiple abilities affect imitation in the preschool years, to further investigate how distinct abilities may underlie children’s copying behaviour.

In summary Study 1 shows that children’s imitation of successive models undergoes significant changes between the ages of 2 and 12 years. Under the age of 5 years children imitated the first model more than the second: this could be due to their poor inhibitory skills or to their inflexible use of labelling. Above the age of 6 years children began to copy both models faithfully, but were at chance as to who to copy on a third turn. By the age of 10 years children copied the present model faithfully on all turns. This increase in model-dependent imitation reflects children’s growing tendency to assume that copying the present model is an important part of social learning situations. This may be driven by their own growing experience in explicit educational settings and related to their increasing tendency to conform on ambiguous tasks. The changes in successive-models imitation observed in this study suggest that imitation is a composite ability affected by multiple abilities, which will be examined in further detail in the ensuing chapters. In particular Chapter 3 will determine whether imitation is modulated by inflexible labelling or action inhibition, and whether imitation can be affected by social factors under the age of 5 years. Chapter 4 will focus on the role of goals in imitation, and examine how changing the perceived goal of an action can affect the fidelity with which it is imitated by pre-schoolers. Taken together these chapters will provide stronger evidence for concluding that imitation is a composite ability which is affected by both low-level mechanisms of action production and by higher-order cognitive processes like goal-attribution.

CHAPTER 3

INTRODUCTION

In Chapter 2 children aged between 2 and 12 years saw two models, M1 and M2, demonstrate different versions of the same game (e.g. "lopping"). One of the models only used functional actions to play the game, whereas the other model included arbitrary actions in their demonstrations. Children were given the chance to play the game once after each model, and once more after both demonstrations, with M1 present again.

There was a substantial effect of age. Children under 3 years would consistently demonstrate the first action sequence they saw by M1 on all three turns, regardless of whether M1 included the arbitrary actions or not. Children under 5 years would copy M2 and $M1_{rep}$ at chance levels. Children above 6 years began to copy each model in turn, and this tendency increased with age, reaching ceiling levels after 9 years. With age children got more accurate at imitating on all three turns: in particular, children under 5 years showed much lower imitation of M2 than the other age groups, and $M1_{rep}$ scores were still at chance until the age of 10 years.

The results from Chapter 2 suggest that there may be developmental milestones in children's imitation occurring before the age of 6 years and at 9 years. To clarify what caused the first milestone I conducted a series of follow-up studies looking at ways to improve imitation of multiple models for children under 5 years. This would show what abilities are guiding children's imitation and would therefore help explain why imitation changes before the age of 6 years.

There were a number of potential explanations to consider for children's lower imitation of M2. One initial factor that I considered was the use of the same novel label by M1 and M2. Successive-models tasks usually show two models, M1 and M2, demonstrating different versions of playing the same new game by using the same label (e.g. "daxing"; Rakoczy et al., 2008). Children under 5 years typically imitate M1's solution and protest against M2's deviant actions. However children at this age are sensitive to context: Rakoczy et al. (2009) looked at how pre-schoolers reacted to deviant models playing a game (e.g. "daxing") in a "wrong" way. Children protested less against the deviant model's actions when this model was playing with objects in a neutral context than when they were playing with objects in an area specifically marked for playing the game “daxing”. It was argued that pre-schoolers therefore understand the context relativity of rules: what counts as a mistake in one context does not count as a mistake in another. This was replicated in a further study by Keupp, Behne, Zachow, Kasbohm and Rakoczy (2015).

Other studies have also suggested that labels may be important in guiding children’s understanding of deviant models. Brandl et al. (2015) have argued that children’s protest towards deviant models in successive-models paradigms may be due to the fact that children dislike the mismatch between what a model says they will do (“I’m going to dax”) and what they actually do (i.e., actions that the child has not seen before for as daxing). Such an argument is related to the mutual exclusivity bias in children’s language acquisition: pre-schoolers tend to avoid using a known word for a novel object, and will assume that a novel object requires a new word (e.g. Diesendruck & Markson, 2001; Markman, Wasow & Hansen, 2003). With reference to the findings from Chapter 2, it is possible that children under 5 years would not imitate M2 as faithfully as M1, because M2 used the same novel label as M1 (e.g. “lopping”) but used a clearly different action sequence. If this is the case, then if the models used different labels to describe their actions, the children should be more likely to imitate both models, as the conflict created by the use of the same label is resolved. This was the aim of Study 2.

STUDY 2

Study 2 tested the possibility that young children’s less frequent imitation of M2 was related to their dislike of M2 calling their action by the same name as M1 but then acting differently. Three- to 5-year-olds were assessed on a successive-models imitation task. The study was identical to the procedure described in Chapter 2, except that I added a control condition for labels. In the Test condition M1 and M2 used the *same* novel label to describe their actions, as had been the case in Study 1. In the new Control condition M1 and M2 referred to their action sequences by *different* labels (e.g. “lopping” vs “daxing”). It is predicted that, if children do not accept the use of the same label for two different actions, then they should imitate M2’s actions more faithfully in the Control condition (*different* condition) than in the Test condition (*same* condition). In contrast if children’s imitation is not affected by the use of alternate labels then there should be no difference between the same label and alternate label conditions. An adult control was included to highlight any age differences that would occur on $M1_{rep}$ imitation beyond the age of 5 years.

METHODS

Participants. This study recruited 45 children from local nurseries and playgroups in the Stirlingshire area. The age range was from 34 to 61 months (M_{age} = 49.5 months, *S.D.* = 8 months, 22 male). Children were randomly allocated to the 'same' condition (M_{age} = 49.4, *S.D.* = 8 months; N = 25; 15 male) and the 'different' condition (M_{age} = 49.6, *S.D.* = 9 months; N = 20; 7 male), with mean age being similar across the two conditions, $t(43) = 0.044$, $p = .97$. Additionally, 10 adults between 21 and 52 years were recruited through opportunity sampling (M_{age} = 26.6, *S.D.* = 9.24 months; 6 male). The study received ethical approval from the University of Stirling Ethics Committee and parental consent was obtained for all children prior to testing. Debrief forms were provided to parents and the nurseries at the end of data collection.

Design. Study 2 used essentially the same design as that of Study 1. One difference was that one group of children received the study in the 'same' condition (as in Study 1) while the other group of children received it in the 'different' condition, where M1 and M2 used a different label (i.e., lopping and daxing; trepping and challing; chokking and sedding; mooshing and bebbing). Order, F_{first} or AF_{first}, was manipulated within subjects. Adults received the study as a within-subjects design and were given two F_{first} and two AF_{first} tasks, one of each in a 'same' and in a 'different' condition.

Materials & Procedure. Study 2 used the same materials as Study 1. The procedure was also identical to that of Study 1, aside from the different labels used in the 'different' and 'same' conditions.

Scoring. Children and adults were scored on how well they imitated the present model on each of the three turns for each game (M1, M2 and $M1_{rep}$). They were coded as either imitating the model (giving them a score of 1 for that model) or not imitating (which gave them a score of 0) using the same criteria as Study 1. The maximum score for each model M1, M2 and $M1_{rep}$ was 4. For reliability purposes, both M1 and M2 recorded the child's responses in a manner identical to Study 1. Both models kept an individual scoring sheet for recording their responses. As the task progressed they each recorded the child's responses on their own sheets and then were able to compare their notes after each child.

Both experimenters were blind to the hypotheses, and agreement between experimenters was perfect.

If children did not respond on one task, their data was not included in the analyses for tasks of that type. This occurred for two children in the F_{First} tasks and one child in the AF_{First} tasks. Thus analyses for these tasks were conducted on the remaining 43 and 44 children respectively. To distinguish between cases where children did not imitate the model because they were using the other model's solution and times when they were doing something different than what was shown by either model, children's responses were also coded using the response patterns set out in Study 1. For instance if children copied M1's actions on all three turns they were coded as "M1-M1-M1". If they copied each model they were coded as "M1-M2-M1" and if they switched to M2 the pattern was coded as "M1-M2-M2". Because transparency did not affect results in Study 1 this factor was not analysed here. I also did not collect protest data due to its low occurrence in Study 1.

RESULTS

Adult Controls. For the adult participants, the labelling condition had a noticeable effect on their imitation scores. Specifically, adults were more likely to imitate M2 and $M1_{rep}$ in the different condition than in the same condition. A repeated-measures ANOVA with model (M1, M2, $M1_{rep}$) and condition (same or different) as within subject factors was conducted. There was a main effect of condition, $F(1, 18) = 14.05$, $p = .005$, partial η^2=.61, and a main effect of model, $F(2, 18) = 4.33$, $p = .029$, partial η^2=.33. There was also a significant interaction between condition and model, $F(2, 18) = 6.21$, $p = .009$, partial η^2=.41. Imitation accuracy for M2 was marginally significantly higher in the 'different' condition ($M = 1.9$, $SE = .10$) than in the 'same' condition ($M = 1.6$, $SE = .10$), $t(9) = 1.96$, $p = .08$, but significantly higher for $M1_{rep}$ (different: $M = 2.0$, $SE = .0$; same: $M = 1.0$, $SE = .26$), $t(9) = 3.87$, $p = .004$). Thus using different labels particularly enhanced $M1_{rep}$ imitation in adults, but not M2 imitation, presumably due to an overall high level of imitation accuracy.

Children's imitation

Preliminary analysis. There was no difference for the M1, M2, and $M1_{rep}$ imitation scores between the four different tasks, Friedman test all *ps* > .24. The sum imitation scores M1, M2 and $M1_{rep}$ were also similar for boys and girls, t-tests all *ps* > .06, and there was no effect of model order, all *p*s > .28. The data was collapsed on these variables and they were not analysed further.

Imitation scores. As observed in Study 1, children imitation varied between the three turns (M1, M2 and $M1_{rep}$). However, going against the predictions (and the results for the adult participants) label condition had no effect on children's imitation, as can be seen in Figure 4. A 2*2*3 mixed factorial repeated-measures ANOVA with label condition (same vs different) as between-subjects variable and order (F_{First} vs AF_{First}) and model (M1, M2 and $M1_{rep}$) as within-subjects variables. The main effect of model was significant, $F(1.6, 65.2) = 26.5$, $p<.001$, partial $\eta^2 = .398$ (Huynh-Feldt correction). There was also a significant interaction between model and order, $F(1.45, 57.8) = 11.2$, $p<.001$, partial $\eta^2 = .219$ (Greenhouse-Geisser correction). No other main effects or interactions were significant, $p>34$. Therefore label had no effect on children's imitation of the models. The interaction between model and order suggested that there were differences between the F_{First} and AF_{First} games, therefore separate analyses were conducted for the two game types. Figure 4 shows children's M1, M2 and $M1_{rep}$ imitation scores for the F_{First} and AF_{First} games, with the label conditions combined.

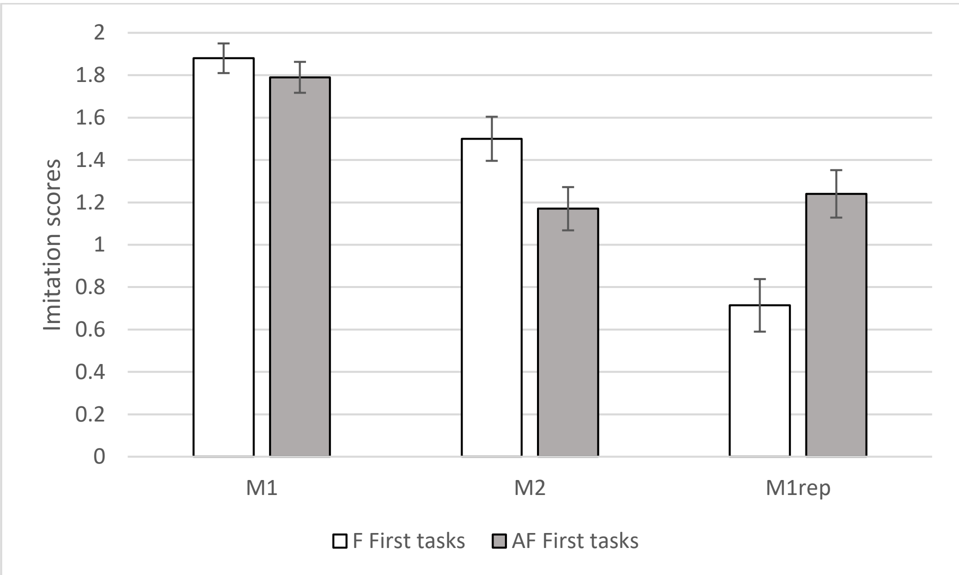


Figure 4. Imitation scores for M1, M2 and $M1_{rep}$ on the F_{First} and AF_{First} tasks. Bars indicate standard errors.

F_{First} tasks. To analyse children's scores on the F_{First} tasks, a 2*3 mixed factorial ANOVA was run with label condition (same vs. different) as a between-subjects variable and model (M1, M2 and $M1_{rep}$) as a within-subjects variable. The type of

labelling condition children were in had no effect on their imitation. The main effect of model was significant, $F(1.49, 61.2) = 30.45$. $p<.001$, partial $\eta^2 = .426$, showing that children imitated M1, M2 and $M1_{rep}$ at different rates. M1 scores were significantly higher ($M = 1.88$, $SE = .07$) than M2 ($M = 1.49$, $SE = .102$) and $M1_{rep}$ scores ($M = .698$, $SE = .122$), $p = .003$ and $p<.001$ respectively. M2 scores were also significantly different from M1rep scores, $p<.001$. This matches the performance of children in this age range for Study 1, as children under 5 years in Study 1 also imitated M1 more frequently than M2 or $M1_{rep}$.

AF_{First} tasks. A similar 2*3 mixed factorial ANOVA was conducted for children's imitation scores on the AF_{First} tasks. There was again no significant main effect of label condition, $p = .322$. Children imitated M1 more than they imitated M2 or $M1_{rep}$, as there was again a main effect of model, $F(1.6, 67.3) = 13.02$, $p<.001$, partial $\eta^2 = .237$ (Huynh-Feldt correction). M1 scores ($M = 1.77$, $SE = .072$) were significantly greater than M2 scores ($M = 1.14$, $SE = .101$) and $M1_{rep}$ scores ($M = 1.23$, $SE = .107$), all *p*s<.001. This time M2 scores were not significantly different from $M1_{rep}$ scores, $p = .585$. When comparing F_{First} and AF_{First} games, M2 scores were significantly higher on the F_{First} games than on the AF_{First} games, $t(41) = 2.65$, $p = .012$ and $M1_{rep}$ scores were significantly lower on the F_{First} games than on the AF_{First} games, $t(41) = -3.6$, $p<.001$.

Given the significant effect of age on imitation in Study 1 correlations between age in months and M1, M2 and $M1_{rep}$ scores were conducted. There was a moderately strong positive correlation between age in months and M2 imitation scores on the AF_{First} tasks, $r = .482$, $p = .001$. Like in Study 1, older children were more likely to omit M1's arbitrary action and imitate M2. There were no significant correlations for other scores on the AF_{First} tasks or on the F_{First} tasks, all *p*s > .23.

Response patterns. Following the coding system set out in Study 1, if a child demonstrated M1's actions on all three trials within a task, it was coded as M1-M1-M1. If a child demonstrated what M1 did on the first round, but then demonstrated M2's actions for the following two rounds it was coded as M1-M2-M2. Finally, children who demonstrated actions of whichever model was present in the room were coded as M1-M2-M1. Unlike in Study 1, the majority of children in Study 2 switched between the two games of each type, resulting in a large number of children displaying a "mixed" pattern (20 children for the F_{First} tasks and 30 for the AF_{First} tasks). However 13 children displayed the M1-M2-M2 pattern for the F_{First} tasks, versus only 5 did so in the AF_{First} tasks. The remaining children were split between displaying M1-M1-M1 (n = 3 for F_{First} and n = 5 for AF_{First}), M1-M2-M1 (n = 4 for F_{First} and n = 5 for AF_{First}) or other nonsense actions and non-responses (n = 5 for F_{First} and n = 3 for AF_{First}). Study 1 had found that the majority of the 4- to 5-year-olds displayed M1-M2-M2 on the F_{First} tasks, preferring to copy M2's use of the arbitrary action on $M1_{rep}$. Whilst this effect was not as prevalent in Study 2, the M1-M2-M2 pattern occurred more on the F_{First} tasks than on the AF_{First} tasks, showing that again between the ages of 3 and 5 years children tended to copy M2's arbitrary action once they had seen it.

DISCUSSION

The aim of Study 2 was to determine whether the low imitation scores of M2 by children under 5 years in Study 1 was due to both models referring to their action by the same name. Previous research has suggested that children under 3 years show a marked tendency to avoid applying new labels to known objects (Casler, 2014) and some have suggested that a similar avoidance of lexical overlap may cause children to protest against deviant models in imitation games (Brandl et al., 2015; Brinck, 2015). I controlled for the effect of labels in Study 2. Children saw M1 and M2 demonstrate different action sequences on the same apparatus. The only difference was whether the models referred to their actions with the same label (same condition) or with different labels (different condition).

Adults seeing M1 and M2 use different labels showed higher imitation scores of both models than when the models used the same label. They may have been sensitive to the implications of the two models' different labels, presumably enhancing their idea of what the game is about (i.e., to copy each model in turn). In contrast, the children did not imitate M2 more faithfully in the different condition than in the same condition. Moreover, imitative fidelity of M2 did not increase in the same condition between the ages of 3 and 5 years, as would be predicted if children became more flexible in their use of labels. Thus, imitative fidelity on the successive-models task is not driven by children's use of labels to constrain what is acceptable (Brandl et al., 2015). Pre-school age children have been shown to be sensitive to whether a model's actions constitute a mistake depending on contextual factors: 3-year-olds use context to decide whether a puppet's actions are allowed or incorrect (Rakoczy et al., 2009). However, in Rakoczy and colleagues' study children evaluated whether a puppet's actions were correct using location (e.g., whether they performed action A in location A and action B in location B) rather than label. In the type of successive-models task used here, the use of two distinct labels used by the two models does not seem enough for pre-schoolers to encourage faithful imitation of both solutions on the same apparatus. Therefore children's low imitation of M2 in Studies 1 and 2 must have been driven by a factor other than labelling.

Children between the ages of 3 and 5 years tended to copy M2 more in the F_{First} tasks than in the AF_{First} tasks (as evidenced by their higher M2 scores and lower M1rep scores). This replicates the finding from Study 1 that children prefer to copy M2 when they are adding an action, even when this action may be seen as arbitrary (although the effect was less strong in Study 2). As children aged, they also became more likely to imitate M2 on the AF_{First} tasks in Study 2, showing that they were more likely to omit M1's arbitrary action to copy M2's actions. This was not observed in this age range for Study 1: although $M1_{rep}$ scores increased between with age on the AF_{First} tasks, this increase was not significant between the ages of 3 and 5 years.

I investigated another factor that may explain the results observed in Study 1. The finding to be explained is that children under 5 years showed less imitation of M2 than M1 on a successive-models task – in particular younger children in Study 1 imitated M1 on all three turns of the task (displaying the M1-M1-M1 pattern). It is only with age that children began to copy M2 as much as M1. One reason younger children may show low M2 imitation scores is their immature inhibition abilities. Under the age of 3 years children display "perserverative errors" (Best & Miller, 2010), where they continue to demonstrate a previously correct response even after the task demands have changed, making that response now incorrect. Consider children's performance on the Dimensional Change Card Sorting task: in this game children have to sort a pile of cards using one of two dimensions. One is colour: e.g. "all red cards go in this pile, all the blue cards go into this one; the other dimension is shape "all boats go in this pile, all dogs go in this pile". Children start off by sorting the cards according to one dimension, for instance colour. After a few turns they are then told that the rule changes and they must now sort the cards with a different dimension, shape. This means that cards which previously went into one pile must now be sorted into a different pile (e.g. blue cards which went into the blue pile must now go into the red pile because the shape matches that of the other cards in that pile). On the classic version of the task 3-year-olds can sort the cards by either dimension in the pre-switch phase but they then perseverate with the first rule in the post-switch phase (Zelazo & Frye, 1998; Zelazo, Carter, Reznick & Frye, 1997).

In the successive-models paradigm used in the above studies, when children perform M1's solution on the object it may be providing them with motor experience of how to perform the task in question, but they may struggle to switch to a different set of action under changed circumstances. According to the ideomotor theory of action production, when an action is performed an action-effect link is formed, consisting of the sensory perception of an action's effect and the motor program associated with it (Hommel, 2009; Paulus, 2014). This link is bidirectional, such that seeing the effect performed primes the observer to perform the action they have seen associated with that effect. Seeing M1 manipulate the object, and then manipulating the object themselves to produce the same effect, allows children to form a motor program between M1's actions and the effect. It is possible that when young children are given the opportunity to imitate M2, they cannot inhibit the motor program formed during M1's turn. M2 uses the same object as M1, and objects can be used to remind observers of the actions performed with them (the "affordances" of the object, Gibson, 1986). M2 also uses one of the same actions as M1 and the child, as both models used the functional action. Accordingly, young pre-schoolers' imitation of M1 over M2 may be due to their poor inhibitory skills, by being unable to stop performing M1's actions. This would explain why they succeed in adding M2's action, but not omitting M1's action. If this is the case, then children's imitation of M2 should increase alongside their motor inhibitory skills.

STUDY 3

In Study 3 I conducted the same successive-models imitation paradigm as in Studies 1 and 2. However in this study I investigated the effect of motor inhibition by varying whether children were allowed to copy M1 and M2 after their turns. Half of the children were allowed to copy M1 and M2 after their turns (copy condition), and half of the children would just observe (no copy condition). All children were given the opportunity to perform the actions at the end in the presence of $M1_{rep}$. According to ideomotor theories of imitation (ASL, Catmur et al., 2009; IMAIL, Paulus, 2014) action experience helps form a link between an action's effect and the motor program associated with that action. Therefore, by removing action experience (i.e., by not letting children copy M1), children should be less likely to perform the action in the initial way demonstrated by M1 on $M1_{rep}$, as the link between the action's effect and the motor program will be less strong. In contrast, children who copy M1 should be more likely to produce M1's actions on $M1_{rep}$. If other factors aside from motor inhibition are constraining children's imitation of M2 at this age, then there should be no difference between the copy and no copy conditions.

To further control for children's inhibitory ability, I included an executive function assessment called the Bear/Dragon task (B/D task, Reed, Pien & Rothbart, 1984). The B/D task is a Simon Says game where children must perform actions when told to do so by the bear and ignore commands given by another, the dragon. It is a measure of children's ability to inhibit their movements and switch between two contradictory responses ("copy" and "not copy", Carlson, Moses & Breton, 2002). In Study 3 children were asked to follow simple instructions, for instance, to touch their nose when it is said by the 'nice' bear, but not to follow these instructions when said by the 'naughty' dragon. Children improve on the B/D task between the ages of 3 and 4 years (Carlson, 2005) which is also an age range where children show marked changes in their imitation (e.g. Yu & Kushnir, 2014; Moraru et al., 2016). If children's inhibitive ability is related to their imitation then, as children age, there should be parallel improvement in children's ability to imitate both models flexibly and their performance on the B/D task.

Finally I included an additional control of the effect of labels following the null result observed in Study 2. In Study 2 labelling had no effect on the fidelity with which children imitated M2 – but it has yet to be investigated whether children's imitation is affected by the simple presence of a novel label in the first place. Keupp et al. (2015) found that children imitated arbitrary actions more faithfully when a novel label was used to highlight the conventionality of the action (e.g. "daxing") as opposed to when the action is framed within the context of an end goal (e.g. "find the puzzle piece"). Keupp et al. (2013) found that pre-schoolers also protested more when a novel label was used. The presence of a novel label may thus encourage faithful imitation of a task and constrain deviant actions once it has been used. To clarify whether the presence of a novel label in comparison to no label affects children's imitation at this age, I controlled for whether the models referred to their actions using labels or whether they simply referred to their actions as "playing the game". Previous work by Keupp and colleagues (2013, 2015) suggests that the presence of a novel label can encourage faithful imitation of arbitrary actions and protest towards deviant models. Therefore if children's dislike for copying M2 is related to M2 referring to their action with M1's novel label, then children should be more likely to imitate M2 if the models do not use labels.

METHODS

Participants. The study recruited 39 children from local nurseries and playgroups in the Stirlingshire area. Four children were excluded from the study for uncooperativeness. The final sample consisted of 35 children whose age ranged between 35 to 62 months (M_{age} = 47.6, *S.D.* = 8 months; 20 male). Children were randomly allocated to the 'copy' condition (M_{age} = 48.06, *S.D.* = 8.3 months; *N* = 16, 8 male) and the 'no copy' condition (M_{age} = 47.17, *S.D.* = 7.8 months; *N* = 19; 12 male), with mean age being similar across the two conditions, $t(32) = 0.33$, $p = .74$. Additionally, half the children in each condition received the task with a novel label (M_{age} = 46.56, *S.D.* = 7.6 months; *N* = 19; 12 male) and the other half with no label (M_{age} = 48.75, *S.D.* = 8.1 months; *N* = 16; 8 male). Again these two groups were comparable in age, $t(32) = 0.82$, $p = .42$. The study received ethical approval from the University of Stirling Ethics' Committee and parental consent was obtained for all children prior to testing.

Design. The same design as Studies 1 and 2 was used for Study 3. One difference was that half of the children saw the two models describe their actions with the same novel label (like the 'same' label condition in Study 1) while the other group of children saw the models demonstrated their actions without using any label. Children also either received the task in the 'copy' condition, where they were allowed to have a go after each model or in the 'no copy' condition in which they watched the demonstrations without being allowed to have a go themselves. This resulted in four different conditions 'copy/label', 'copy/no label', 'no copy/label' and 'no copy/no label'. The order of the models (who was M1 and M2) was maintained constant throughout all four games. Order, F_{first} or AF_{first}, was manipulated within subjects. All children additionally received a Bear/Dragon task at the end of the session.

Materials & Procedure. Study 3 used the same materials as those used for Studies 1 and 2. The procedure was the same, apart from some groups receiving the task either with a novel label or without a label and some groups either being allowed to copy or not being allowed to copy the present model. Additionally I included a Bear/Dragon task (Reed et al., 1984) to measure children's inhibitory strength. A bear hand puppet and a dragon toy were used for this task.

Children were introduced to both models in the nursery, brought individually to the testing location by both experimenters and sat down at a table, with the first model (M1) sitting opposite them. Once the child was sat down M2 excused herself and left the room.

Copy + Novel Label. This condition was identical to the procedure for the 'same label' condition in Study 2. Children observed M1 and M2 demonstrate different methods of performing the same novel game which they referred to by the same label (e.g. "lopping"). Children were asked to play the game after M1's turn, then after M2's turn and then once more at the end by M1.

Copy + No Label. The procedure was the same as for the Copy + Novel Label condition except that now the games were not referred to by their novel names. Instead at the beginning of the session M1 said "Now I'm going to show you how to play a new game. This is how the game goes". After that both models always referred to their actions with "And that's how you play the game" and "Now I'm going to play the game". When M1 returned they asked the child "Now you know how to play the game. Can you do it one more time?"

No Copy + Novel Label. In the No Copy conditions the children were not given the opportunity to play the game until after they had seen both models perform the task and M1 returned. Like in the copy conditions, M1 and M2 both demonstrated their action sequence twice, but children were not given the opportunity to imitate the task after their solutions. In the label condition they referred to the game with a novel label.

No Copy + No Label. In this condition the procedure was exactly the same as in the No Copy + Novel Label condition, except that in this condition the tasks were not referred to with their novel labels. Therefore as in the Copy + No Label condition both models' prompts referred to "playing the game".

Bear/Dragon task. After all four imitation games were completed and the materials cleared away, the male experimenter said "Right, now we're going to play a new game. Now in this game, you have to copy me." They then modelled ten simple body movements, naming the movements as they performed them (e.g. "Can you touch your nose? Touch your tummy? Stick out your tongue?"). After these *warm-up rounds* (at which all children succeeded) the experimenter said "Very good! Now we're going to play this game again, but we're going to play it with some friends of mine". They then reached into the boxes and brought out the Bear and Dragon toys. The experimenter placed the Bear toy on their right hand and said "Now this is *Nice Bear* – he's very nice. So when he tells us to do something, we'll do what he tells us to do". When saying Nice Bear's name the experimenter took on a high-pitched voice, and used this voice for all of the Bear's instructions during the task. Next the experimenter held the Dragon in their left hand and said "Now this is *Naughty Dragon* – he's naughty. So when he tells us to do something, we won't do what he tells us to do". When saying Naughty Dragon's name the experimenter took on a deep voice, and used this voice for all of the Dragon's instructions.

After this the *practice phase* began. In this phase, children were given ten instructions, five from the Bear and five from the Dragon, beginning with the Bear and alternating between the two puppets. During this practice phase, if a child made a mistake, that is, not doing what the Bear said or following the Dragon's instructions, they were reminded of the rules. The experimenter said "Whoops! Remember the rules!" and then re-read the instructions for the toys from the start of the game. If a child made 5 mistakes in a row (n = 9), they were encouraged to sit on their hands and listen to a sixth set of instructions. Regardless of how the child did on this final sixth turn, they received no feedback and they moved to the test phase of the task. Once the child correctly reacted to one instruction from both puppets they were praised with "That's right! Good!" and the test phase of the task began. The *test phase* again included the same ten body movements as in the previous phases of the task and proceeded in the same way as the practice phase, except that the child did not receive any feedback. The child had three seconds to respond to or ignore every instruction. Once all ten instructions had been given, the child was praised effusively, thanked for their help and escorted back to the nursery.

Scoring. For reliability purposes, both M1 and M2 recorded the child's responses in the same way as in Studies 1 and 2. Both models kept an individual scoring sheet for recording the child's responses – M1 had theirs next to the table for data collection and M2 had theirs next to their waiting spot outside of the room (from which they could see the child). As the task progressed they each recorded the child's responses on their own sheets and then were able to compare their notes after each child. There were no disagreements between the models.

During the imitation games children were defined as either copying the present model or not. Children who imitated the model needed to touch the object(s) used by the model and use them in the same way to bring about the same goal. This resulted in a binary coding score where children who demonstrated the solution used by the present model received a score of 1, and children who did not received a score of 0.

Children's response pattern (M1-M1-M1, M1-M2-M2 and M1-M2-M1) was only analysed for the 'copy' condition, as children in the 'no copy' condition could only copy on the final turn, so their responses were only coded for $M1_{rep}$.

B/D data was recorded by the experimenter not involved in the task. The coding scheme used was that laid out by Carlson et al. (2002): children were scored on each of the actions during the five dragon trials. Scores ranged from 0 to 3: 0 = a full commanded movement, 1 = a partial commanded movement, 2 = a wrong movement, 3 = no movement (Max_{corr}= 15).

RESULTS

Preliminary analysis. There was no difference for the M1, M2, and $M1_{rep}$ imitation scores between the four different tasks, Friedman test all *ps* > .19. The sum imitation scores M1, M2 and $M1_{rep}$ were also similar for boys and girls, t-tests all *ps* > .33, and there was no effect of model order, all *p*s > .13. The data was collapsed on these variables and they were not analysed further.

Imitation scores.

Label conditions. I investigated whether children in the 'copy' condition were affected by the presence/absence of novel labels on the three model imitation scores. There was no effect of label: children who saw the tasks presented with novel labels did not imitate differently from children who saw the tasks presented with no label at all. A mixed factorial repeated-measures ANOVA was conducted on the imitation scores with model (M1, M2, $M1_{rep}$) and order (F_{first} vs AF_{first}) as within subject factors and condition (label or no label) as between subject factor. Replicating previous results, there was a main effect of model, $F(2, 28)$, = 8.35, p = .001, partial η^2 = .37. M1 scores were highest (M = 1.97, SE = .03), while M2 scores (M = 1.19, SE = .16) and $M1_{rep}$ scores (M = 1.34, SE = .15) were significantly lower but similar to each other. No other main effects or interactions were found. Thus, using a novel label (M = 1.52, SE = .07) or no label (M = 1.48, SE = .07) in the copy condition did not affect their overall imitation scores (p = .66).

Copy conditions. I ran analyses to see whether children's imitation of $M1_{rep}$ was affected by whether or not they were allowed to copy M1 and M2. I compared children's $M1_{rep}$ scores on the F_{First} and AF_{First} tasks (within-subjects factor) between the four conditions (Copy + novel label; No copy + novel label; Copy + no label; No copy + no label). B/D task scores were included as a covariate to control for inhibitory ability. Overall, there were no main effects and no significant interactions of copy or labelling, all *p*s>.18. There was however a significant main effect of B/D task scores, $F(1, 30) = 5.68$, p = .024, partial η^2 = .159. Figure 5 shows the mean $M1_{rep}$ imitation scores for all four conditions, showing that there was no effect of copy condition or labelling.

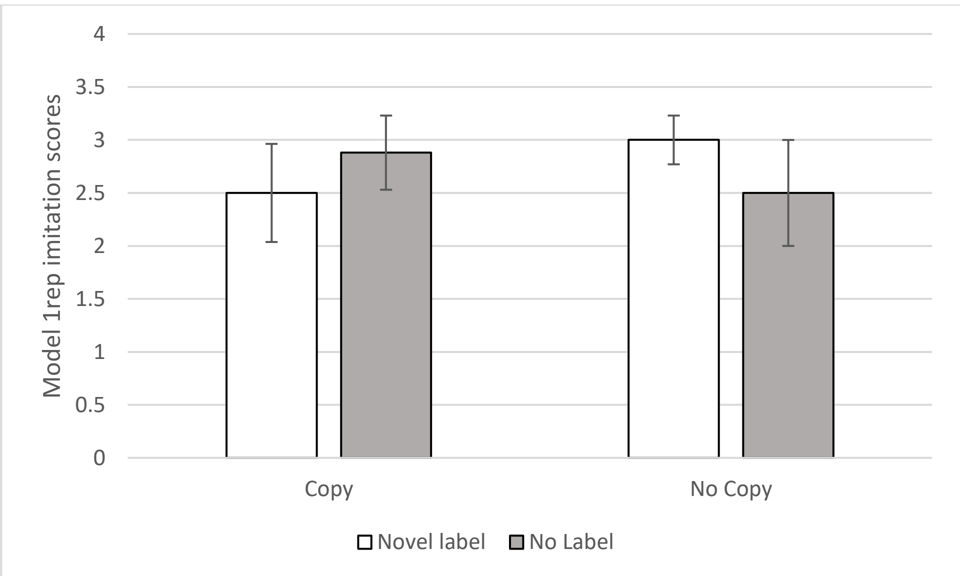


Figure 5. $M1_{rep}$ imitation scores between the four conditions. Bars indicate standard errors.

Response patterns. Looking at the copy condition, children replicated M1's actions on all three turns (M1-M1-M1 pattern) 21 times (33%). The M1-M2-M1 pattern was shown 19 times (30%), and copying M1 but then switching to M2 (M1-M2-M2 pattern) was observed 21 times (33%). This matches findings from Study 2: children do not show a preference for one response pattern over another. The response pattern data for Studies 2 and 3 differ from that of Study 1 which found clearer response pattern preferences in children this age.

Bear/Dragon scores. Children's performance on the B/D task increased with age, as has been found for children aged between 3 and 4 years (Carlson, 2005). With age children were increasingly able to inhibit copying the Dragon's actions, $r = .64$, $p < .001$. Additionally, the B/D score correlated negatively with $M1_{rep}$, $r = -.37$, $p = .03$, but with no other score. When children were allowed to copy M1's arbitrary actions, they were more likely to omit them on $M1_{rep}$'s turn if they had good inhibitory control ($r = -.53$, $p = .04$). But inhibitory control had no effect on $M1_{rep}$ in the 'no copy' condition ($p = .53$). In the 'copy' condition, age was also positively correlated with M2 scores on the AF_{First} tasks, $r = .47$, $p = .06$, as well as negatively correlated with $M1_{rep}$ scores on the AF_{First} tasks, $r = -.64$, $p = .008$. This means that when children were allowed to imitate M1's arbitrary action, like in Study 1, only older children omitted the arbitrary action on M2's turn and would continue to omit it for $M1_{rep}$'s turn.

DISCUSSION

The aim of Study 3 was to investigate whether children's imitation of successive models was related to their inhibitory ability. I conducted the same imitation task as in Study 2 – but in this study half of the children were allowed to imitate M1 and M2 after their turns, and half were only allowed to perform the task on $M1_{rep}$. A B/D task as a measure of children's inhibitory ability was also included and one group of children saw the task with a label while the other group saw it without a label.

Firstly, replicating the results from Study 2, there was no effect of label on imitation. Children's copying of M1, M2 or $M1_{rep}$ was not affected by whether the models used novel labels to refer to their actions or no labels. This provides more evidence that labelling does not affect 3- to 5-year-old children's imitation of successive models in a game-like context. Secondly, going against the predictions, there was also no effect of copy condition on children's imitation. Children in the copy condition did not imitate $M1_{rep}$ more than children in the no copy condition. Thus, although it may have had an effect on younger children, if 3- to 5-year-old children received motor experience during M1 and M2's turns, this did not make them more likely to produce a specific solution on $M1_{rep}$'s turn. Children's imitation of $M1_{rep}$ was not affected by whether or not they had copied M1 and M2, which is what would have been expected if children's perseverative imitation of M1 was due to their having formed a motor program of M1's actions on M1's turn. A more stringent test of action experience could be applied, for instance by varying which model returned on the final go. Children who had imitated M1 may be more likely to use M1's actions rather than M2's actions on the final turn, even if M2 was present on this final turn. But if this is not the case, then merely observing the two models use different action sequences on the same object could be enough to reduce imitation to near-chance levels.

While whether children were allowed to copy or not had no effect on their imitation on $M1_{rep}$, there was however a link between children's B/D scores and their imitation. Children with higher B/D scores tended to receive lower $M1_{rep}$ scores, but only in the copy condition. This means that children who were better at inhibiting their actions were also more likely to omit M1's arbitrary action after having seen M2 perform the task without it. In the no copy condition there was no such relationship. Yet in both the copy and no copy conditions, there was a strong positive correlation between age in months and B/D scores, showing that while children's inhibitory ability was just as strong in the no copy condition, it did only affect their imitation in the copy condition.

In the AF_{First} tasks of the copy condition, there was also a positive correlation between age and M2 scores and a negative correlation between age and $M1_{rep}$ scores. Like in Study 2, as children aged, they became more likely to omit M1's arbitrary action and only use M2's functional action on M2 and $M1_{rep}$'s turns. Given the correlation between age in months and B/D scores, it is possible that this effect is driven by children's growing inhibitory abilities, as children become more likely to be able to inhibit their actions with age.

In the no copy condition, where children did not imitate M1 and M2, their inhibition ability did not affect the likelihood of imitating either model on $M1_{rep}$. This is to be expected, as ideomotor theory would argue that it is only when one is experienced with an action that the automatic action-effect link will interfere with action production (Paulus, 2014). When children merely observed M1 perform their actions they did not form a strong action-effect link, which therefore did not need to be overcome when imitating M2 and $M1_{rep}$. Inhibition is thus not required to imitate either model when children have not had to copy M1 and M2. Study 3 shows that children's responses on successive-models imitation tasks can be affected by the general action control process of motor inhibition. If children copy M1, only children who have the ability to inhibit actions can omit parts of this first action sequence when that model returns on $M1_{rep}$. This is what would be predicted by generalist accounts of imitation (such as ASL, Catmur et al., 2009; and IMAIL, Paulus, 2014) which argue that imitation shares general action processes used in non-imitative action production. Imitation fidelity is modulated by general action control characteristics (such as inhibition or whether the action is feasible for the child to do, Paulus et al., 2011).

It should however be noted that inhibitory ability had no effect on whether children would *include* the arbitrary action: neither B/D scores nor age in months were related to children's imitation scores for M2 on the F_{First} tasks, where M2 added the arbitrary action. Other theories of imitation (affiliative and normative accounts) do not predict that children should react differently to a deviant model omitting versus adding actions. The social affiliative account would predict that children should copy the deviant model's actions equally regardless of what they are, and the normative account predicts that children should not imitate a deviant model regardless of whether they add or omit from the original action sequence. It is possible that generalist accounts of imitation may predict this, as they state that imitation is always imitation *of a specific action*: rather than requiring specialised imitative mechanisms (such as the active intermodal matching system, Meltzoff, 1995) imitation involves general processes of action control, of which inhibition is one. Omitting an action may simply be harder than adding an action on the type of task used here, which is the only reason why older children could do so (as their inhibitory skills were better than the younger children).

Study 3 showed that 3- to 5-year-old children find it harder to omit arbitrary actions than add them in, as only children with higher inhibition scores omitted M2's arbitrary action on $M1_{rep}$ in the copy condition. Children's inhibitory abilities may thus not be fully developed under the age of 5 years, which would explain why in Study 1 only children above 6 years could imitate the models on their turns. However, it may be possible to encourage children's imitation of M2 under the age of 5 years by varying another factor which has been shown to enhance children's imitation. One such factor from previous research on successive-models tasks is model reliability. Previous studies using successive-models tasks (Rakoczy et al., 2008; Keupp et al., 2013) typically have an adult as M1 and a puppet as M2. In such studies children prefer to imitate the actions of the adult M1 over the deviant puppet M2. Rakoczy et al. (2010) found that adults were imitated more faithfully than children in a successive-models task, regardless of whether the adult is M1 or M2. Wood, Kendal and Flynn (2013b) argue that adults as a social group are typically seen by pre-schoolers as more reliable models than peers. In Studies 1 to 3, M1 and M2 appear as equally reliable models, as they are similarly aged adults and no practice phase establishes one model as less reliable than the other (as is the case in other studies, Rakoczy et al., 2008; Keupp et al., 2013). Children thus have no reason to prefer one model's actions over the other. However if one of the models was a puppet, then children may avoid copying them and will always prefer to imitate the actions of the adult.

The next study, Study 4, investigated a potential model identity effect to see whether it could encourage the inhibitory skills identified in Study 3. In a similar successive-models task to Studies 1 to 3, 3- to 5-year-old children observed M1 and M2 demonstrate different methods of performing the same action. Here, unlike previous studies, one of the models was an adult and the other was a puppet. Previous studies (Keupp et al., 2013; Rakoczy et al., 2010; Wood et al., 2013b) would predict that children will prefer to imitate the actions of the adult over the actions of the puppet. This model identity bias may interact with inhibitory skills, and thus may show that younger pre-schoolers can imitate M2 (even when this require omitting a known action) if the two models are distinct. If so, this would be evidence that, despite lower inhibitory skills, children are capable of omitting an action, even if they have previously copied that action. It is possible therefore that children's imitation of successive models will be affected by the types of model children see.

STUDY 4

The research question of Study 4 was whether children's imitation on a successive-models task would be affected by varying model identity between M1 and M2. The same design as Studies 1 to 3 was used: children observed M1 and M2 demonstrate different methods of performing the same novel game (e.g. "lopping"). Children were allowed to copy after each model and then once more in the presence of M1. One model was an adult, whereas the other model was a hand-puppet – I varied which model was M1 and which was M2. On the basis of the findings from Study 3, it is predicted that children should find it harder to imitate M2 when M2 is omitting the arbitrary action. However when M1 is a puppet and M2 is an adult, children should also be more motivated to copy M2 (as adults are typically seen as more reliable than puppets). If children therefore show greater imitation of M2 when M2 is an adult omitting an action, this would be evidence that children's inhibitory skills are sufficiently developed to let them copy both models, but they required an additional distinction between the models to imitate M2. Similarly, if model identity affects imitation, then children should be more likely to copy M2 adding the arbitrary action when M2 is an adult than when they are a puppet. If children show lower imitation of M2 (omitting an action) regardless of model type, then inhibition is the main reason children did not copy M2 as much as M1 in Studies 1 to 3.

METHODS

Participants. This study recruited 32 children from a Scottish nursery aged between 41 and 60 months (M_{age}= 50.6 months, *SD* = 5.9, 17 male). This sample was randomly divided into a group that saw the puppet as M1 (*N* = 16, M_{age} = 50.8 months, *SD* = 5.1, 6 male) and a group that saw the adult as M1 (*N* = 16, M_{age} = 50.4 months, *SD* = 6.8, 11 male) which were not significantly different in age, p = .86. Children were predominantly from a middle-class background and took part if they had written parental consent and if they volunteered on the day of testing. Ethical approval for this study was obtained from the Psychology Ethics Committee at the University of Stirling and debrief forms were given to the parents and the nursery involved.

Design. Study 4 used the same general design as Study 1. The only difference was that one adult model was replaced by a puppet model. Half of the children (*N* = 16) saw the Puppet as M1, and the other half saw the Puppet as M2. All children saw two F_{first} and two AF_{first} tasks, whereby the order, F-F-AF-AF or AF-AF-F-F, was varied between children (8 children saw either order in both the Puppet M1 and Puppet M2 conditions).

Materials & Procedure. Study 4 used the same materials as the previous studies. Additionally, the study used a lion hand puppet as the puppet model.

To avoid the possibility that children would be confused by seeing an adult manipulate the puppet, the male experimenter who controlled the puppet was hidden from view from the child at all times. To ensure this, testing was conducted at a table upon which was set a wooden stage-like frame with a curtain. The male experimenter was blocked from view by a wooden partition around the stage. When the experimenter stuck their arm through the curtain only the puppet was visible to the child. Figure 6 provides a description of the set-up used in Study 4.

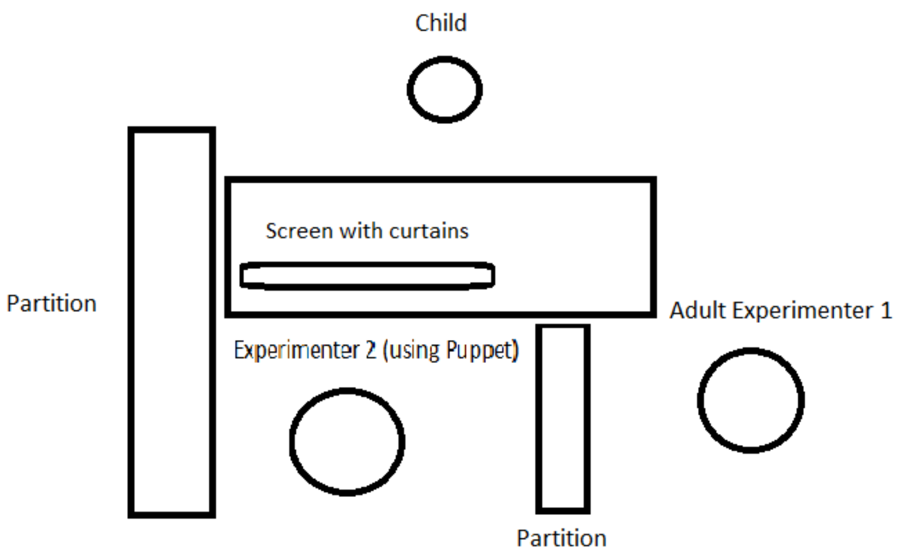


Figure 6. View of the set-up used in Study 4 seen from above.

Children were brought to the table by a staff member from the nursery. The male experimenter always manipulated the puppet - a female experimenter always played the role of the adult model. Children were tested individually in a separate room of the nursery. At the start of the testing session the puppet, named Bill, and the adult model, named Maria, introduced themselves to the children. The children were invited to sit at a desk which had the curtain set up on it. Then M2, either the puppet model or the adult model, left. In the case of the puppet model, this meant that the puppet retreated behind the curtain; the adult model left the testing area and disappeared from view. M1 then began the script for either the F_{first} tasks or the AF_{first} task. The procedure and the scripts followed those of Study 1. Like in Study 1, if after any of the demonstrations children did not respond, then after 5 seconds the model said “Go on, you can have a go, it’s fun!” If the child still did not respond for 5 seconds then the model said “Would you like me to show you again?” after which they repeated their lines and actions for their demonstration.

Coding. Coding was conducted in the same way as Studies 1 to 3. For reliability purposes, both M1 and M2 recorded the child’s responses. Both models kept an individual scoring sheet for recording their responses – M1 had theirs next to the table for data collection and M2 had theirs next to their waiting spot outside of the room (from which they could see the child). As the task progressed they each recorded the child’s responses on their own sheets and then were able to compare their notes after each child. One of the experimenters was blind to the hypotheses of the study. There were 3 cases of disagreement between the experimenters but these were resolved through discussion.

RESULTS

Preliminary analyses. There was no difference for the imitation scores M1, M2, and $M1_{rep}$ between the four different tasks, Cochran’s χ^2 all *ps* > .57. The sum imitation scores M1, M2 and $M1_{rep}$ were also similar for boys and girls, t-tests all *ps* > 16. There was also no effect of action order (F_{First} vs AF_{First}), $p = .11$. These variables were therefore not analysed further.

Imitation scores. A mixed factorial ANOVA was conducted on children’s imitation scores, with model (M1, M2, $M1_{rep}$) and game (F_{First} vs AF_{First} tasks) as within-subjects factors and model order (Puppet M1 vs Puppet M2) as a between-subject factor. As in Studies 1 to 3 the children imitated M1, M2 and $M1_{rep}$ at different rates, as there was a main effect of model, $F(1.18, 32.9) = 21.25$, $p<.001$, partial $\eta^2 = .431$ (Greenhouse-Geisser correction). Consistent with previous research there was also a significant main effect of model order, $F(1, 28) = 4.52$, $p = .043$, partial $\eta^2 = .139$ and a significant interaction between model and model order, $F(1.18, 32.9) = 4.18$, $p = .043$, partial $\eta^2 = .13$ (Greenhouse-Geisser correction). No other effects were significant, $p > .08$. Children were significantly more likely to copy M2 when M2 was an Adult ($M = 3.1$, $SE = .23$) than when M2 was a Puppet ($M = 1.93$, $SE = .25$), $t(28) = 3.36$, $p = .002$, $d =$

1.22. There were no other differences on other model scores, p = .165 and p = .359 for M1 and M1rep. Figure 7 gives the M1, M2 and $M1_{rep}$ scores between the Puppet M1 and Puppet M2 conditions.

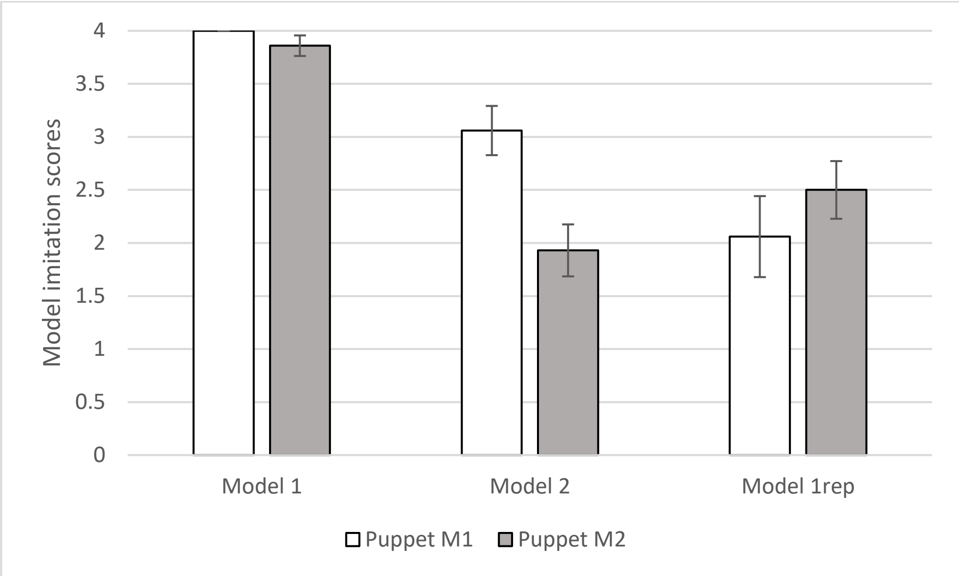


Figure 7. Model imitation scores between the Puppet M1 and Puppet M2 conditions. Bars indicate standard errors.

In the Puppet M1 condition of the AF_{First} tasks, age was positively correlated with M2 scores (r = .56, p = .02) and marginally negatively correlated with $M1_{rep}$ scores (r = -.46, p = .08). So when children saw the adult omit the puppet's arbitrary action, only the older children would omit it. In the Puppet M2 condition no such correlations were found (ps > .27): older children were not more or less likely to imitate the Puppet (M2) than younger children. Hence, when the puppet omitted an action, children of all ages were less likely to omit the action themselves. In contrast, when the puppet was M1 and the adult was M2, only older children were more likely omit the puppet's arbitrary action. The younger children did not make such a difference.

Response Pattern. Children replicated M1's actions on all three turns (M1-M1-M1 pattern) 49 times (38%). The model-dependent imitation (M1-M2-M1 pattern) was shown 25 times (20%). Copying M1 but then switching to M2 (M1-M2-M2 pattern) was observed 50 times (39%). This matches findings from Study 2 and 3, in that children did not have a strong preference for either response pattern.

DISCUSSION

The aim of Study 4 was to see if children's imitation on a successive-models task was influenced by the identity of the models. Children were allowed to imitate two models performing different versions of the same novel task: one of the models was a puppet and the other was an adult. As in Studies 2 and 3, whilst performance on the F_{First} tasks did not change with age, with increasing age children became more likely to imitate M2 on the AF_{First} tasks. However in Study 4 this effect was only present when M2 was the adult, as when M2 was a puppet children's age was not related to their imitation of M2. Children were also more likely to imitate an adult as M2 regardless of whether the adult was omitting or adding an arbitrary action. Therefore model identity interfered with the age effect observed in previous studies: older children tended not to omit arbitrary actions if the model doing so was a puppet.

The results of Study 4 suggest that children were more likely to imitate actions that were modelled by the adult and would not imitate the puppet as much. These findings match on to previous studies showing that children seem to prefer actions modelled by adults over those modelled by puppets (Rakoczy et al., 2008) or children (Rakoczy et al., 2010). The findings also suggest that even though older children could omit the arbitrary action used by M1 in order to copy M2 (as they did when M2 was an adult), they did not do so when M2 was a puppet. As age was shown to be correlated with inhibitory ability in Study 3, it is possible that children's inhibition was modulated by the identity of the model. Following the IMAIL account of imitation (Paulus, 2014), children are better at imitating actions that are in their own "motor repertoire" (Paulus et al., 2011; Hunnius & Bekkering, 2014). One of the reasons children did not imitate puppet as much may have been because they have less experience in imitating puppets: but this would have predicted that children should also have shown less imitation of M1 if M1 was a puppet, which was not found.

Another possibility is that the distinctness between the two models helped children dissociate the two action sequences. In Studies 1 to 3, where M2 is consistently imitated less than M1 by 3- to 5-year-olds, the two models are adults of equal reliability. In Study 4 the two models were very distinct: one is an adult and the other is a toy, manipulated in a pretend context. Three- to 5-year-olds have been shown to be sensitive to changes in context when imitating (Rakoczy et al., 2009), so the change in context may have allowed children to decide that they could imitate a different model. If the context between two models remains too similar, then children may not imitate a deviant model's solution if they are attempting to do the same task as the previous model.

The findings from Study 4 suggest that successive-models studies which compare a puppet and an adult should take into account the model-based biases pre-schoolers show at this age. In particular children may have the ability to successfully imitate a new action sequence, but may not do so if the model demonstrating it is less reliable than the original model. Alternatively, children can deviate from M1's previously demonstrated action sequence to copy M2 if M2 is more reliable than M1 (as shown by Rakoczy et al., 2010). Children do not do so if the two models are seen as equally reliable (as was the case in Studies 1 to 3, where M1 was imitated more than M2).

So far, the studies in this chapter have tested several aspects of the successive-models task to determine why children imitated M2 and $M1_{rep}$ less than M1. Labelling has no effect on children's imitation in the type of task used here: Study 2 showed that children did not imitate M2 more faithfully if the two models used different labels, and Study 3 showed that children did not M2 more faithfully if neither model used labels to describe the task. However, children's ability to deviate from M1's actions was related to their inhibitory ability, but only when this involves omitting arbitrary actions they had previously performed (Study 3). Finally Study 4 showed that children imitate M2 more faithfully if they appear to be a more reliable model than M1 (as indicated by model identity). However there is another factor that remains to be investigated: the fact that M1's object is always present during M2's turn and that M1 and their object is present during $M1_{rep}$.

In Studies 1 to 4, a consistent finding is that 3- to 5-year-olds are at chance as to who to imitate on $M1_{rep}$. M1 and M2 always demonstrated their action sequences on the same object, which means that when children imitate on $M1_{rep}$, they perform their action on the object used by either model. This could explain why they are at chance as to what action to do, as they have seen the object used for either action. By the age of 2 years children understand objects as being "for" certain purposes. Casler and Kelemen (2005) presented evidence that after seeing a model demonstrate actions with novel tools, 30-month-olds see novel tools as "for" that specific function (similar results have been found in 2- and 4-year-olds, DiYanni & Kelemen, 2008; Casler, 2014). Gibson's theory of affordances (Greeno, 1994) would suggest that objects remind learners of the actions associated with them. This would explain why actions on objects tend to be imitated earlier than actions on bodies (Christie & Slaughter, 2009; Kim et al., 2015) as objects, unlike body movements, can be associated with salient effects (Paulus, 2014). The object serves as a cue to remind children of the actions they observed. If this explanation can account for why children are at chance as to who to copy on $M1_{rep}$, then one way of encouraging imitation of $M1_{rep}$ would be to provide the two models with different objects. This way, children will not have seen the same object used for both actions. On $M1_{rep}$, children should therefore be more likely to imitate the only action they have seen the object used for.

A further variable to control for is which model returns on the final turn. In Studies 1 to 4, M1 was always present for children's third turn, which means that it is unclear how children would respond if M2 was present instead. Nielsen and Blank (2011) conducted a successive-models task where M1 and M2 demonstrated two different action sequences on the same object to 4-year-olds. After seeing the two models demonstrate their action sequences, children had a go at the task themselves, in the presence of either M1 or M2 (the other model left the room). In contrast to other studies (Rakoczy et al., 2008; Keupp et al., 2013) children did not show a preference for always copying M1's action, but were more likely to imitate the action sequence of whichever model was present. In Nielsen and Blank's study (2011) the two models used the same object, which may have had an effect on the results. M1 and M2 also demonstrated their actions in each other's presence, which may have been interpreted by children as a cue that they could imitate either action sequence (as opposed to Studies 1 to 4 in this thesis where M1 and M2 were not present during each other's turns).

Study 5 thus controlled for both model presence and the object used by either model. Using another successive-models paradigm, children participated in five conditions. One condition, used as a control, had children observe two models demonstrate different action sequences on the same object (as in Studies 1 to 4). However in the other conditions, M1 and M2 demonstrated their different action sequences on two differently-coloured versions of the same object (e.g. on red and yellow cylinders). When it came to the child's own turn to play, they were either in the presence of M1 or M2, using either their own object or that used by the other model.

This set-up will help tease apart the effects of the combination of model and object presence, to see if children's imitation is affected not only by who is present, but by what they have previously seen the object used for.

STUDY 5

The aim of Study 5 was to investigate how children imitate when the actions cued by the model and by the object were mutually exclusive. A similar successive-models task to the previous studies in this chapter was used: 3- to 5-year-old children saw M1 and M2 demonstrate different methods of playing the same game (e.g. "zerping") with some novel objects. One of the models only used a functional action (e.g. pushing a button to turn on a light) whereas the other model would also include an arbitrary action (e.g. lifting the box and placing it on its side first). Given that model presence affects imitation when children do not copy each model in turn (Nielsen & Blank, 2011), like in Study 3 (no copy condition) children only imitated once, after having seen both models' demonstrations. This also removed the potential confounding effect of a lack of inhibition, as Study 3 showed that pre-schoolers find it difficult to omit actions they have previously performed in this type of successive-models task.

There were five conditions in all: in the control condition, children saw M1 and M2 perform their actions on the same object. This matched the previous studies used in this chapter and would allow for comparison with these studies, which is important as Study 5 used different materials to see whether the results of Study 1-4 could be replicated in a non-game-like context. In the other four conditions, two factors were varied: whether the model returning used their own object or that used by the other model, and whether the returning model had used the functional action only, or the arbitrary action as well. In the Functional Own condition, children were asked to perform the task by the model who had previously used only the functional action (the other model was absent): the functional model gave the child the object they themselves had used (for the functional action). This means that children were asked to perform the action in the presence of the model who did the functional action, and were given the object used for the functional action to do so, In the Functional Other condition the object the children used had been previously manipulated by the other model with the arbitrary action. In the Functional and Arbitrary Own condition, the present model on the child's turn had used both the functional and arbitrary actions and gave the child their own object to imitate with. Finally in the Functional and Arbitrary Other condition, children imitated in the presence of the model had used both the functional and arbitrary actions, but the children used the object used by the other model for only the functional action.

The set-up of Study 5 will help tease apart the effects of model presence and experience with an object. If children are most sensitive to the presence of the model, they should copy the action associated with the present model regardless of the object that is being used. This would indicate that their primary motivation in the setting is to imitate the present model (Over & Carpenter, 2011). The social function of imitation becomes prevalent during the second year of life and particularly after the age of 2 (Kim et al., 2015; Nadel, 2002) and children grow more sensitive to social cues such as eye contact with age (Marsh, Ropar & Hamilton, 2014). It is possible that as children get older the model might become a more important cue in guiding children's imitation. Older children in this sample may therefore be more likely to copy the present model regardless of the present object.

In contrast if children are more sensitive to the object being used then they should copy the action associated with the present object, regardless of who asks them to have a go. This would be expected if children's expectancies with objects is the main cue guiding their imitation. Observational experience can allow infants to predict action outcomes (Hunnius & Bekkering, 2014); seeing salient effects paired with a movement on an object can prime infants to perform that action if they see the effect (Paulus, Hunnius & Bekkering, 2013). The presence of an object associated with a salient effect may make children more likely to focus on reproducing that effect, if their imitation is still mainly being driven by action-effect binding as it is in infancy.

An additional factor controlled for was the effect of inhibitory ability. Whilst Study 3 showed that inhibitory ability had no effect on children in the no copy condition, it was always M1 who returned on the final turn of the task ($M1_{rep}$). Here the order of the model returning after both models' demonstrations was varied, so that it was sometimes M1($M1_{rep}$) and sometimes M2 ($M2_{rep}$). Inhibitory ability may be required to demonstrate different actions to the ones used by the present model. In addition it may also require greater inhibitory ability to demonstrate the action used by M1 when M2 has just demonstrated their action and asks the child to do the same

($M2_{rep}$) as this action sequence may be easier for children to recall and perform. To find out, children also participated in the B/D task used in Study 3. If their inhibitory ability allows them to perform the actions of the model who is not present then there should be a relationship between children's imitation scores and their B/D scores. If not, then this will further support the claim that inhibition is only required for imitation in certain contexts, and is not involved when children have no motor experience of the task in question.

METHODS

Participants. Children were tested at three nurseries across the central belt of Scotland. All nurseries were located in middle-class areas, but this was not controlled for data recruitment. Fifty-nine children were tested for this study, but one girl was excluded for uncooperativeness. The final sample consisted of 58 children with a mean age of 45.6 months (*SD* = 9 months, ranged from 25 to 70 months, 28 male). Parental consent was received before testing began, debrief forms were given to the nurseries after data collection and the study was approved by the General University Ethics Panel at the University of Stirling. Only children who agreed to help the experimenters on days of data collection participated in the study.

Apparatus. Five pairs of custom-made objects were used (see Table 2): the two objects in each pair were identical but painted in different colours. The objects were used for five different games, each referred to by a novel made-up word. For the "Daxing" game, there were two sealed cardboard tubes containing three bells each. The "Trepping" game used two sealed cardboard tubes each containing a handful of dried peas. The "Zerping" game had two boxes, both of which had LED push lights attached to the top and right sides of the boxes. The lights were activated by pushing the lights in. The "Lobbing" game used two more boxes, but these had two switches located on the top of the box. One of the switches was white and the other was black. For the "Mooshing" game there were two boxes which could be opened. A handle was on the top of each box to make opening the lid easier, and inside were many coloured stickers of faces. As mentioned above the two models used different actions on the two versions of the object. Table 3 shows the functional actions and the arbitrary actions performed on each pair of objects.

For the Bear-Dragon (B/D) task, children saw two hand puppets, a brown bear and a green dragon that were similar in size.

Table 3. Materials and actions used in Study 5.

Name	*Materials*	*Size*	*Functional action*	*Arbitrary action*
Daxing		3 ½ x 3 ½ inches	Turn the object on its side and shake it from side to side, producing a noise	Hold the object upright and move it anti-clockwise in a circle twice
Trepping		3 x 10 inches	Turn the object on its side and shake it from side to side, producing a noise	Rotate the object forward one full turn
Zerping		4 ½ x 4 ½ x 4 ½ inches	Turn on the side light and then the top light	Lift the box and place it on its front, then return to start position
Lobbing		4 ½ x 4 ½ x 4 ½ inches	Press the black switch in and then the white switch in	Tap the right side of the box twice
Mooshing		4 ½ x 3 ½ x 9 inches	Turn the box right side up and open the lid	When the box is on its front, knock the top of the box twice

Design. The study was a mixed design including both between-subjects and within-subjects variables. The first task for all children was the B/D task. The two female experimenters each manipulated one of the puppets: the model manipulating the Bear puppet was then M1 for all of the following five imitation games. Model order was counterbalanced between children but consistent across all of the games.

There were five imitation games for children to play. The first was always the control task, in which M1 and M2 performed their action sequences on the *same* object, after which M1 asked the child to have a go at playing the game with that object (similar to Study 1 but with different materials). The order of the other games was counterbalanced between children using a Latin Square Design. The order of the action sequences demonstrated by the two models was also varied. For half of the children M1 would always demonstrate only the functional actions on all five games, and M2 would always display both the functional actions and the arbitrary actions. For the other half action order was reversed.

Procedure. Children were tested individually at the different nurseries. Children were introduced to the two female experimenters who sat opposite them, one on their right and one on their left. The B/D task was always demonstrated first: at the start of the testing session children were introduced to the two puppets, a "nice bear" and a "naughty dragon". They were then instructed by M1 (holding the bear) to copy the actions instructed by the bear, and not to copy the actions instructed by M2 (holding the dragon). There was a practice phase during which the bear and the dragon each gave instructions for four actions, e.g. "touch your head", alternating between them (bear – dragon – bear – dragon …). After each instruction the child was given 4 seconds to respond. If children responded incorrectly they were immediately reminded of the rules, after which the game would resume. If children made three consecutive incorrect responses they were encouraged to sit on their hands for the remaining practice trial. Regardless of how children performed on the four practice trials, after these were done children were given four test trials. Again the bear and dragon gave four instructions each. No acknowledgment was made of mistakes during the test trials. The results for each action were recorded by the alternating model during the other's turn. After the B/D task was complete, M2 left the room and M1 told the child that they would play some new games.

Control condition. In the control condition M1 brought out materials from a box behind them and placed them on the table. In the control condition only one object was used for both models. M1 announced that they would show the child how to play a new game, referring to it by its label: “Now I’m going to show you how to play zerping. Watch this!” M1 then demonstrated their action sequence on the object three times. After the demonstration M1 excused themselves and left the room whilst M2 returned and sat at the table with the child. M2 also announced that they would play the game: “I’m now going to play zerping. Watch this!” M2 demonstrated their action sequence three times, and this was always the alternative action sequence to what M1 had done. After demonstrating their action sequence M2 also excused themselves and left the room whilst M1 came back. M1 said “Would you like to play zerping now? Can you show me zerping?” and proffered the object to the child. In the control condition children saw M1 and M2 show their actions on the same object, but were always asked to demonstrate the actions in the presence of M1.

The other four games all included a similar procedure to the control game, but in these four games M1 and M2 demonstrated their actions on differently coloured objects. Further to this, it was varied whether M1 or M2 came back and asked the child to play the game once more.

Functional Own task. On the Functional Own task, the model who had demonstrated the functional action (M1 or M2) was present on the child’s final turn. They offered the child the object that they themselves had used. Therefore when asked to have a go, children were in the presence of both the model and the object that had previously been used for the functional actions only.

Functional Other task. On the Functional Other task, children were again asked to play the game by the model that had used only the functional action. However they gave the child the object that had been used by the *other* model to demonstrate the arbitrary and functional actions.

Functional and Arbitrary Own task. The procedure was identical to the Functional Own condition, but instead of the child being asked to play the game by the model who had done the functional action only, they were asked to do so by the model who had performed both the functional and arbitrary actions.

Functional and Arbitrary Other task. On this task, children were asked to play the game by the model who had previously shown them the functional and the arbitrary actions. But the object they gave the child had been used by the other model who had demonstrated only the functional action.

After playing all five games, children were thanked for their participation and returned to their nursery class.

Scoring. On the B/D task the same scoring system was used as in Study 3: scores ranged from 0 to 3: 0 = a full commanded movement, 1 = a partial commanded movement, 2 = a wrong movement, 3 = no movement. In this study however due to time constraints only 4 bear trials were administered to children. This mean that children's scores on the B/D task could range from 0 to 12 (Max_{corr}= 12). A higher score indicated better inhibitory skills.

Children's imitation was scored separately for the functional and arbitrary actions on each task. For both of these actions, children could score 0, 1 or 2. A score of 0 meant that they did not produce the action at all. A score of 1 meant that they performed part of the action but not all of it, and a score of 2 meant that they performed the full action. In the analysis the control condition was looked at separately to the other four imitation games, to compare it with the same condition from Studies 2, 3 and 4 where M1 and M2 used the same object and M1 would return, but children were allowed to copy each of them. The other four conditions will be used to examine the effect of the presence of the object and the model.

For reliability purposes, both M1 and M2 recorded the child's responses. Both models kept an individual scoring sheet for recording their responses – M1 had theirs next to the table for data collection and M2 had theirs next to their waiting spot outside of the room (from which they could see the child). As the task progressed they each recorded the child's responses on their own sheets and then were able to compare their notes after each child. There were no disagreements between the two models.

The imitation scores do not give us the specific responses made by each child. Therefore children were also coded on whether or not they copied the actions displayed by the present model on the imitation tasks. If children copied what the present model had done they received a coding of "copying the present model". They received this coding regardless of whether they performed full or partial imitation of the present model's actions. If they did not copy what the model had done, but displayed the action sequence displayed on the object, they were coded as "copying the object". If children did not respond or performed another action that was not either of the models' actions they received a coding of "other".

RESULTS

Preliminary analysis. Gender did not affect children's imitative behaviour on any of the five imitation tasks, all *ps* > .16. Therefore this was not analysed further.

In the control condition M1 and M2 demonstrated their actions on the same object and M1 was always present during the child's turn. To investigate whether using the same object affected children's copying behaviour, I compared the control condition with another condition in the study in which M1 and M2 used different objects and M1 returned with her own object. A mixed factorial repeated-measures ANOVA with action type (functional vs. arbitrary) and condition (same vs. different object) as within subject factors and action order (F_{First} vs. AF_{First}) as between subject factor was conducted.

The ANOVA found a main effect of action type: functional actions (*M* = 1.59, *SE* = .07) were imitated more often than arbitrary actions (*M* = .62, *SE* = .09), $F(1, 56) = 162.8$, $p < .001$, $\eta^2 = .74$. Action type interacted significantly with action order, $F(1, 56) = 6.75$, $p = .012$, $\eta^2 = .107$: functional actions were imitated at equal rates regardless of action order, but arbitrary actions were more often imitated, when they were shown by M1 present on the child's turn (*M* = .88, *SE* = .13), than when they were shown by M2 who was not present on the child's turn (*M* = .36, *SE* = .1). Surprisingly, no main effect of condition was found (*p* = .79), indicating that children's imitative behaviour was not affected by whether M2 used the same or a different object than M1.

Imitation scores. After having looked at the control condition, I looked at how children's imitation varied between the other four test conditions. The mean scores for functional and arbitrary actions are summarised in Figure 8. A mixed factorial repeated-measures ANOVA was conducted on the four test imitation scores with model present (functional model vs. arbitrary + functional model), object present (present model's object vs. other model's object) and action type (functional vs. arbitrary) as within subject factors and action order (F_{First} vs. AF_{First}) as a between subject factor. The main effect of action type observed in the control tasks was also present for these tasks, $F(1, 56) = 310.22$, $p < .001$, partial η^2=.847. Functional actions were imitated more accurately (M = 1.68, SE = .05) than arbitrary actions (M = 0.70, SE = .06). There was also a main effect of model presence, $F(1, 56) = 4.91$, $p = .031$, partial η^2=.081, such that models performing the arbitrary actions were imitated more often (M = 1.28, SE = .07) than models who performed only the functional actions (M = 1.10, SE = .06). There was no main effect of object type (own vs other, $p = .73$) or action order (functional first vs arbitrary + functional first, $p = .31$).

Interestingly, model presence interacted with objects significantly, $F(1, 56)$ = 9.90, $p = .003$, partial η^2=.15. In the presence of the model who had used the functional action, arbitrary action scores where higher when this model used the other model's object (i.e., the object that was associated with the arbitrary action). Conversely, in the presence of the model that had demonstrated the arbitrary action, arbitrary action scores were higher when this model used her own object. Taken together, these findings show that children preferred to copy the longer action sequence, and would imitate it more faithfully if the model used the object seen with that action sequence. Upon including inhibition as a covariate this interaction and the effect of model presence disappeared (all *ps* > .39) suggesting that inhibitory skills played a crucial role in children's preference to copy longer action sequences over shorter ones.

Finally, there was an interaction between model presence and action type, $F(1, 56) = 5.44$, $p = .023$, partial η^2=.09. Regardless of the model, children were highly likely to show the functional action, but in the presence of the model that had also presented the arbitrary action, children were more likely to also show this additional action. Again this effect vanished upon entering inhibitory skills ($p = .59$).

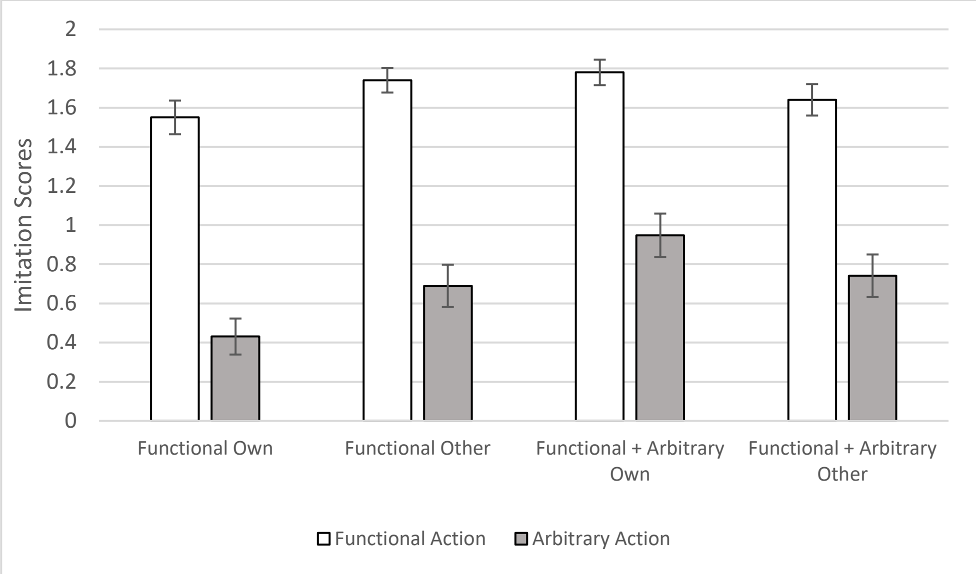


Figure 8. Imitation scores for Functional and Arbitrary actions on the Own and Other tasks. Bars indicate standard errors.

Figure 9 shows children's responses on the Other tasks: as can be seen children did not have any preference for copying either the action of the model or that of the object on the Other tasks.

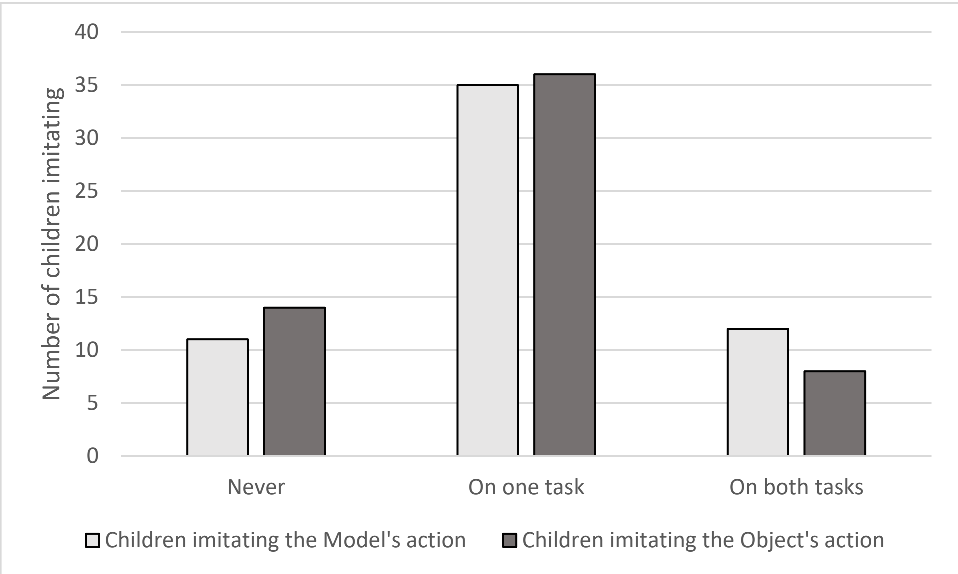


Figure 9. Children's responses on the Other tasks.

DISCUSSION

In Study 5 three- to 5-year-olds were shown two models, M1 and M2, attempting to play the same novel game (e.g. zerping). M1 and M2 demonstrated different action sequences on two different versions of the same object. Both models produced a functional action leading to a salient effect, but one of the models also produced an arbitrary action that had no effect. Children were then given the opportunity to play the game themselves: in some cases the model gave the child the object they themselves had used (e.g. M1 gave the child M1's object). In other cases however the model gave the child the object used by the other model (e.g. M1 gave the child M2's object).

Overall, children imitated functional actions at much higher rates than the arbitrary actions: this is not surprising given that M1 and M2 both demonstrated the functional actions. Children are sensitive to frequency information from infancy (Paulus, Hunnius, Wijnegaarden, Vrins, van Rooij & Bekkering, 2011). The fact that children saw the functional actions twice as often as the arbitrary actions (they were shown by both models and on both objects) could have caused higher rates of functional action imitation. The level of imitation of the functional actions also did not vary greatly between the different game types (i.e., which model and which object was present).

However the likelihood of children producing the arbitrary action was significantly affected by the model/object combination. When children imitated in the presence of the model who gave the child their own object, they were significantly more likely to copy the action used by that model. This led to higher arbitrary action scores in the Functional + Arbitrary Own task and lower arbitrary action scores in the Functional Own task. Children's arbitrary action scores were higher in the Functional Other and Function and Arbitrary Other conditions than in the Functional Own task. This suggests that children's preference to copy the arbitrary action was enhanced through the presence of the object on which that arbitrary action had been demonstrated previously. Both the object and the model that had previously been used for the arbitrary action encouraged imitation of that arbitrary action.

As in the other conditions, children were more likely to imitate the arbitrary action in the control condition when M1 (present during the child's turn) had also used it. This reflects findings from Nielsen and Blank (2011) who also found that children were more likely to imitate arbitrary actions when the model who had produced them was present during the child's turn. The presence of the model was enough to encourage imitation of that model's actions – this showed that in the absence of motor experience, children's imitation was affected by the presence of the model.

Study 5 shows that children's imitation can be affected not only by the way they have seen an object manipulated, but also by the combination between the object and the model present during the child's imitation. The finding that children imitated arbitrary actions more on the Functional + Arbitrary Other task than on the Functional Own task suggests that seeing an object used for an arbitrary action is enough to encourage imitation of that action. On the Other tasks, children did not have a clear preference for displaying either the action used by the model, or the action associated with the object, as evidenced by the equal number of children copying the actions of the object and the model in Figure 8. However if the model and object present on the child's turn had both been seen demonstrating the same action, children were more likely to imitate that action. It is the combination of cues that heightens imitation of a specific action rather than one cue over the other.

GENERAL DISCUSSION

Successive-models paradigms have been used to study how children react to seeing two models demonstrate different methods of performing the same task. How children imitate both models shows how they conceive of the actions of either model, and therefore can be determine what factors drive pre-schoolers' imitation. In Chapter 2 of this thesis I conducted a successive-models task with children aged 2 to 12 years. Age was shown to have a large effect on imitation of successive models: children under 3 years would only copy what M1 had done and not copy M2 at all. It was not until the age of 6 years that children began to imitate both models. As children aged they became more likely to copy $M1_{rep}$ and M2 on their respective turns. The aim of the current chapter was to isolate different variables that may have explained why children under 5 years were less likely to copy M2 than older children. Studies 2 to 5 looked at these factors to help isolate what is driving children's imitation at this age.

The type of labels used by the models to describe their actions had no effect on imitation – Studies 2 and 3 found that children under 5 years did not copy M2 more when they used a different label to M1. Similarly Study 3 found that children did not imitate more faithfully if the models referred to their actions using a novel label, as opposed to with no label at all. Children's copying behaviour under the age of 5 years was not affected by the labels used by the model to describe their actions. Pre-schoolers will use labels in a mutually exclusive way to determine what labels and facts can be associated with objects (Casler & Kelemen, 2005; Casler, 2014; Diesendruck & Markson, 2001). However 2-year-olds do not show this mutually exclusivity for artefact functions: they will use known objects for new purposes rather than believe that they cannot be used for multiple goals (Casler, 2014). Schmidt et al. (2011) also found that labels are not necessary to encourage high-fidelity imitation (and protest towards deviant models) in pre-schoolers. In the type of game task used here, labelling did not affect the way children imitated the models: labelling therefore was not the main factor explaining why children under 5 years showed lower imitation of M2.

Another consistent finding in Studies 2 to 4 was that children's tendency to copy M2 increased with age particularly on the AF_{First} tasks. As children got older, they were more likely to omit the arbitrary action used by M1, and use the shorter action sequence demonstrated by M2 on both M2's turn and on $M1_{rep}$'s turn. Study 3 suggests that this age difference may have been due to children's growing inhibitory abilities – the better children were at inhibiting their actions on a version of the B/D task, the better they were at omitting M2's arbitrary actions on $M1_{rep}$'s turn. However this was only the case if children had imitated M1 themselves: if children had not copied M1's arbitrary action then omission of an arbitrary action was not related to their inhibitory ability. If imitation involves omitting an action that children have already performed, this will only be possible for children who can inhibit their own actions. However motor inhibition ability was not the only factor affecting children's imitation. In the no copy condition of Study 3 there was no relationship between children's B/D scores and their imitation: inhibitory ability is thus only required when children need to omit an action they have themselves already performed.

Other factors aside from motor experience also affect imitation in pre-schoolers. Study 4 showed that children preferred to copy certain models over others. Pre-schoolers were more likely to copy M2 if M2 was an adult than if M2 was a puppet, regardless of whether M2 added or omitted an arbitrary action. This fits with previous research showing that adults tend to be imitated more faithfully than children between the ages of 3 and 5 years (Rakoczy et al., 2010; McGuigan et al., 2011). Children's avoidance of imitating the puppet actually interfered with the inhibition effect mentioned earlier: if M1 was an adult and M2 a puppet, then children did not become more likely to omit M1’s arbitrary action after seeing M2 do so. Children’s inhibition can thus be modulated by their evaluations of the model they are imitating. The distinct effects of children’s inhibitory ability and their model evaluations can interfere with one another, which further suggests that imitation is a composite of multiple abilities.

Study 5 investigated whether children under 5 years were more influenced by actions they had seen a model do or by the way they had seen an object being used. Children tended to copy the action sequence of whichever model was present: this effect was enhanced when the model was present with their own object. The arbitrary action was also more likely to be performed if one of the present cues (the object or the model) had previously been seen using the arbitrary action. Children’s encoding of actions is thus sensitive to the identity of the model present during their turn and the actions they have seen associated with the object in question. If one wishes to encourage children to learn multiple ways of performing tasks in different ways, dissociating the context between them seems to encourage their imitation of multiple solutions (as context is an important factor determining imitation, Hunnius & Bekkering, 2014). Dissociating the context can be done by varying the presence of the model and the presence of the object (see also Rakoczy et al., 2009).

The results from Studies 4 and 5 show that model identity and object associations both influence children’s imitation under the age of 5 years. Children are more likely to copy actions demonstrated by an adult if the alternative model is a puppet – in particular children will not omit an adult’s arbitrary action if the model demonstrating such an omission is a puppet. Similar findings come from Keupp et al. (2013) – in their study 3- to 5-year-olds who had imitated an adult model M1 would not deviate from their solution after seeing a deviant puppet model M2, and continued to display arbitrary actions at much higher rates than chance. The identity of the model can thus be used to counter children’s growing tendency to omit arbitrary actions as their inhibitory ability grows. In the absence of motor experience with a task, the presence of a model encourages children to imitate those model’s actions. Under the age of 5 years children’s imitation is therefore not only guided by factors such as action inhibition, but is also affected by the associations they make about objects and models.

The results from this set of studies suggest that the identity and presence of a model may in fact encourage or discourage children to inhibit their actions. Studies 2 to

4 found that children's tendency to omit arbitrary actions increased between the ages of 3 to 5 years. But Schleihauf et al. (2017, Experiment 1) found that 5-year-olds would not omit arbitrary actions once they had performed them, even if they saw a second model perform the same task without the arbitrary actions. A crucial difference however with the present studies was that in Schleihauf et al.'s study, models were not present for the child's turn. Model presence and interactivity has been shown to enhance children's imitative fidelity of arbitrary actions (Nielsen et al., 2008; Marsh et al., 2014), therefore model presence may have encouraged children to inhibit their actions. Thus children may not lack the ability to inhibit their actions (as children at this age could do to some extent in Studies 2 to 4 of this chapter), but require the presence of a deviant model to encourage them to inhibit certain actions. This would explain why children became more likely to omit M2's arbitrary actions with age in the studies from this chapter and yet 5-year-olds did not in Schleihauf et al.'s study (2017). Model presence may therefore encourage both the omission of arbitrary actions and their production (as was observed in Studies 4 and 5).

The results from Chapter 3 suggest that under the age of 5 years children's imitation is guided by internal, low-level action production mechanisms, expectancies about object use and social cues such as the presence and identity of the model. Furthermore characteristics of the social learning situation can affect the extent to which low-level factors like action inhibition are employed in imitating successive models. The ASL and IMAIL accounts of imitation (Catmur et al., 2009; Paulus, 2014) suggest that higher-order cognitive processes can modulate the basic mechanisms of action production, for example by inhibiting the priming of a motor response. This chapter finds evidence for such influences here: model presence and a bias for copying adults over puppets can both encourage inhibition or production of actions children have previously performed. Sensitivity to model identity grows throughout the preschool years as children become more sensitive to the potential reliability of different models (Wood et al., 2013b; Bernard et al., 2015). Children also seem to become more aware of the social consequences of their actions after the age of 2 years (Kim et al., 2015), and 2-year-olds are more likely to imitate a model who can interact with them (Nielsen et al., 2008). These biases will modulate the existing mechanisms of action-effect binding that help foster imitation in infancy (Paulus 2012, 2014). Higher-order cognitive capabilities also imitate automatic imitation beyond childhood:

attributing intentions to a model has been found to enhance both automatic imitation effects (Liepelt et al., 2008) and automatic eye gaze following (Teufel et al. 2010) in adults. Children's imitation will thus be modulated throughout childhood as their cognitive abilities encourage different responses and these affect the basic action matching processes involved in infancy.

Taken together, the findings from Chapter 2 and Chapter 3 suggest that imitation is affected by the development of several abilities throughout childhood. Faithful imitation of successive models requires a certain level of inhibition if it involves overcoming one's own motor experience. This ability develops between the ages of 3 and 5 years (Study 3) and suggests that one of the reasons children did not imitate M2 as faithfully as they had M1 was because they could not inhibit their previously formed response of performing M1's actions. However a key point consistently found across Studies 1 to 4 was that once the 3- to 5-year-olds had seen M1 and M2's action sequences they were at chance as to which one to copy on $M1_{rep}$. Similarly in the control condition of Study 5 children's imitation of the arbitrary action did not rise above chance level. The use of the same object by the two models thus caused a conflict, with the object becoming an ambiguous cue. Similarly when the model and the object have been associated with different actions, there is a dilemma and children cannot decide which one to imitate (as in the Other conditions of Study 5). Between the ages of 3 and 5 years children did not show a strong preference for displaying either action sequence on $M1_{rep}$. Once having seen two models manipulate the object in a certain way, children used either action sequence rather than being committed to one. This matches findings by Wood et al. (2013b): 5-year-olds who acquire two ways to open a box either through personal exploration or direct instruction show no preference for either solution and demonstrated either solution equally often.

Whilst 3- to 5-year-olds imitated $M1_{rep}$ (and to some extent M2) at chance levels, Study 1 showed that children above the age of 6 years were just as likely to imitate M2 as M1, and children above 10 years were more likely to imitate $M1_{rep}$ as M1 and M2. The social pressure to imitate the present model may only affect older pre-schoolers: children grow more sensitive to social cues between the ages of 5 and 8 years (Marsh et al., 2014) and more sensitive to conformity for reproducing ambiguous actions between the ages of 3 and 10 years (Haun et al., 2013). The results from Study 3 further support the argument made in Chapter 2 that children above 5 years *could* have imitated $M1_{rep}$ on the final turn, but they did not interpret this as the goal of the task. Rather it was only above the age of 6 years that children began to automatically assume that the goal of the game was “copy the model that is present”.

The way children interpret the goal of the task may thus be an important factor determining how children imitate successive models. Chapter 4 will investigate the role that goal understanding plays on children’s imitation: I will review the evidence that goals affect the way children copy other people’s actions. I will then conduct some studies to show that children’s imitation will change depending on the way they interpret the goal of the task. This will provide further evidence that the change observed in children’s imitation of successive models at the age of 10 years was due to an increased desire to copy the present model over performing the task a certain way.

To summarise, Chapter 3 provides evidence that children’s imitation in successive-models paradigms is guided by both low-level action mechanisms and by higher-order social learning biases. In line with Chapter 2, it is shown that children do not automatically imitate successive models, but are influenced by the identity of the model, the object the models use, and the children’s own previous experience with the task. I have shown in Chapter 2 that children seem to infer social goals (i.e. “copy the present model”) towards mid- to late-childhood in successive-models tasks, whereas children under 5 years will use either action sequence on this type of task once they have seen it performed by two models. Finally, imitation, whilst involving only basic mechanisms of action-effect binding, can be influenced in a top-down manner by children’s evaluations of the identity of the model, their object associations and their goal within the learning situation. In Chapter 4, I extend this concept of goals to see how children’s perceptions of the goals of actions affects their imitation, and whether it is possible to modulate their copying behaviour by changing the goals associated with a model’s actions.

CHAPTER 4

INTRODUCTION

For many years researchers have been interested in why children demonstrate high-fidelity imitation, particularly when this compromises efficiency. For example, why would a child faithfully copy tapping a box with a stick, when directly opening the box without tapping it would also get them the reward (e.g., Nielsen & Blank, 2010)? Do children interpret the tapping movement as deliberate (i.e., the agent has a good reason for doing what they do) and thus mistakenly deem it causally necessary to achieve the goal (Lyons et al., 2011; Lyons et al., 2007)? Or do they regard these movements as normatively prescribed, such that this is what one ought to do (Kenward et al., 2010; Kenward, 2012; Keupp et al., 2013, 2016)?

Chapters 2 and 3 investigated how imitation changes throughout childhood, and helped determine what influences children's imitation of arbitrary actions at different ages. Under the age of 5 years children's imitation depends on the type of movement that is to be performed: if it requires children to overcome a previous motor response then only children with sufficient inhibitory skills can imitate multiple models (Study 3). Pre-schoolers' imitation on this type of task is also affected by the identity of the model (if that model is deemed reliable – Study 4) and by the model-object combination (Study 5). And whilst the ability to imitate successive models on the same game is in place by the age of 6 years, children at this age show no preference for either model's solution once they have seen both. In contrast, 10-year-olds and older children had a clear preference for copying M1 on her return. One possible explanation for this difference (besides that of changing low-level mechanisms) is that children's interpretation of the task changed: the social goal of copying the present model became more important for older children (Marsh et al., 2014).

Two theories reviewed in Chapter 1 (GOADI, and the theory of direct perception) also suggest that the way an action is imitated is related to the goals (in the goal-oriented sense, Perner & Doherty, 2005) that children associate with that action. In particular children reproduce the actions that are associated with goals if those goals are explicit or emphasised (Elsner & Pfeifer, 2012). Known goals are associated with known motor patterns which allow action prediction and imitation (Gampe et al., 2015). Whilst goal inference is not necessary for imitation to occur (Leighton et al., 2010;

Rumiati & Tessari, 2002) inferring the goal of an action can modulate one's imitation of that action in a top-down manner. Froese and Leavens (2014) suggest that perceiving the goal of an action biases one's perception and imitation of that action, for instance by making the learner focus on reproducing the same end goal as the model, at the expense of reproducing the model's exact movements.

Children's imitation appears to be biased by their understanding of action goals from very early on in their development. Infants as young as 15 months prefer to reproduce a model's presumed outcome over reproducing the model's exact movements. In a seminal paper by Meltzoff (1995) infants observed an adult attempted to pull a dumbbell apart, but failed to reach that goal. Quite reliably 18-months-olds pulled the dumbbell apart, despite not ever having seen the dumbbell disassembled. Reproduction of the presumed goal of failed actions has been replicated for 18-months-olds (Bellagamba & Tomasello, 1999) and for 15-months-olds, but not for 12-months-olds (Johnson, Booth, & O'Hearn, 2001). Eighteen-months-olds are also more likely to reproduce intentional actions marked with "There!" than accidental actions, marked with "Whoops!" (Carpenter et al., 1998) Finally, 14- and 16-months-old infants reproduce actions more often if they are relevant to a goal (e.g., remove a Velcro latch from a lid the child is trying to open) than actions which are non-functional to that goal such as removing the latch from a different, unrelated box (Bauer, 1992; Brugger, Lariviere, Mumme, & Bushnell, 2007). Despite these actions being virtually identical infants in their first year of life copy them in a distinct fashion depending on the context.

The findings from Brugger et al.'s study (2007) show that infants prefer to reproduce actions that lead to salient effects over actions performed without salient effects. Similar findings come from Kim et al. (2015) who observed that 18-month-olds would prefer to copy actions on objects that led to salient effects than actions that led to no effect. Jones (2007) has also observed that infants do not reliably imitate arbitrary actions (that is, actions that do not lead to salient effects) until the second year of life. According to IMAIL theory, salient action effects guide imitation of behaviour by becoming associated with the motor program used to bring about that effect (Paulus, 2014). Actions without salient effects are imitated later in development because it is only with age that children learn to form associations between actions and less salient effects. Kim et al. (2015) noted that social consequences of a child's actions (such as a person looking where the child has pointed) do not encourage repeated imitation of those actions as much as salient object effects (such as a light turning on at the push of a button). Under the age of 2 years, infants focus primarily on bringing about salient effects.

In contrast to infants, older pre-schoolers show an increase in their tendency to copy actions performed without salient effects (Hilbrink et al., 2013; Marsh et al., 2014; McGuigan et al., 2011; Nielsen & Tomaselli, 2010; Nielsen, 2006; Xu & Kushnir, 2013). For example, if an adult taps a box with a stick before opening the lid, by preschool age children reliably copy the tapping movement before opening the box themselves, and this tendency increases with age (Horner & Whiten, 2005; Keupp et al., 2013; McGuigan & Graham, 2010; McGuigan et al., 2011; Moraru et al., 2016; Nielsen & Blank, 2011; Whiten et al., 2016). Different theories explaining such faithful copying have been proposed: some have argued that children at this age believe all actions are causally relevant to achieve the end-state (Lyons et al., 2011, 2007); others suggest that children imitate to affiliate with the model ((Nielsen & Blank, 2011; Over & Carpenter, 2012a, 2012b); whilst again others have suggested that children interpret the arbitrary actions as normatively prescribed in the context of the game (Keupp et al., 2013, 2016; Rakoczy et al., 2009).

Older children's imitation has also been shown to vary according to the context. Specifically, children imitate movements more faithfully if these movements are performed in the absence of a plausible external goal. For example, Bekkering et al. (2000) had 3- to 6-year-olds observe an adult moving their hands towards either two dots on the table (*context present*) or towards two unmarked locations (*context absent*). Children copied the model's exact hand movements (i.e. the model reached to their right with their left hand, crossing their midline in a contralateral movement) more faithfully in the context absent conditions than in the context present conditions. Gleissner et al. (2000) reported a similar finding for manual gestures, whereby 3-year-olds copied gestures more accurately when demonstrated *near* a body part (e.g., grasping air next to the ear) than when the gestures were demonstrated *on* the body part (e.g., touching the ear). Carpenter et al. (2005) also found that 12- to 18-months-olds, who had witnessed a mouse being hopped across the table, would copy the hopping movement less often when the mouse was put into a house than when it was simply placed at an unmarked location on the table.

Recently, a theory of imitation was proposed by Schachner and Carey (2013) that explains both imitation of arbitrary actions, and why actions are imitated more faithfully when they are performed without context. The argument is that, because children cannot attribute an external goal to arbitrary actions, they assume that the movement itself is a goal. Broadly speaking, adults naturally assume that movements are means to an end (e.g.: Blum & McHugh, 1971; Baker, Goodman & Tenenbaum, 2009; Lombrozo, 2010; Schneider, Slaughter & Dux, 2017). For example, pressing the button of a coffee maker achieves the goal of getting a coffee. Adults thus interpret the actions of others as having goals (Froese & Leavens, 2014). Some movements, however, lack clear goal-directedness. Watching somebody repeatedly jump up and down may trigger speculations about the underlying goal. When adults watch an animate agent perform actions without any relevant context (e.g. jumping up and down and from side-to-side), they are more likely to infer that the movements themselves were the goal than when the same actions are performed in a relevant context (e.g. knocking coloured balls into colour-matched boxes; Schachner & Carey, 2013). This could explain why children and adults copy movements that are not essential to a final goal, a behaviour sometimes referred to as "over-imitation", "super-copying" or "high-fidelity imitation" (McGuigan et al., 2011): they interpret these actions as a separate but valuable goal. Schachner and Carey (2013) proposed that replication of arbitrary actions may be an instance of "movement-based" goal emulation.

Schachner and Carey's account could also explain why infants and children copy identical actions selectively depending on the context: they infer external goals when a context is present (e.g. the goal is to put the mouse in the house) and are less likely to focus on replicating the model's exact movements (or movements unrelated to that external goal, as in Brugger et al., 2007). In contrast infants infer movement-based goals when a context is absent (e.g. the goal is to hop the mouse), leading them to copy the movement itself more faithfully. In high-fidelity imitation studies, pre-schoolers interpret the arbitrary actions as having movement-based goals, leading them to imitate them faithfully.

The aim of this chapter was to determine whether high-fidelity imitation in pre-schoolers is affected by varying the type of goal children associate with the actions of the model. Studies 6 and 7 set out to extend the findings of Schachner and Carey (2013) using a similar study design to Carpenter et al. (2005) and Gleissner et al. (2000). The objective of Study 6 was to see whether previous findings could be replicated, with movements without context being imitated more faithfully than movements performed with a relevant context. After replicating findings from the previous literature, Study 7 investigated whether children's high-fidelity imitation of arbitrary actions could be modulated by providing the model's arbitrary actions with a secondary external goal, rather than just being an arbitrary action performed without context.

STUDY 6

In Study 6, 2- to 5-year-olds saw object- and body-related actions either in the context of an external goal or without such a context. For instance in one object-based task coloured coins were hopped (*Movement Style*) either towards a box and slotted in it (*Context, C*) or towards pre-defined locations on the table (*No Context, NC*). By Schachner and Carey's (2013) reasoning, movement-based goals should be inferred to a greater extent in NC because the hopping movement does not directly achieve an external goal. Children should therefore replicate the hopping movement more often in NC than in C. Similarly, in the body-related tasks the experimenter performed a movement in a distinctive way (e.g. crossing her arms and lifting them to shoulder height) that either had a visible goal or did not. In C the experimenter touched her shoulders and rubbed them, while in NC she performed the rubbing action without touching her shoulders whilst holding her arms crossed. Because the action achieved an external goal in C but not in NC, children were expected to infer a movement-based goal for the model's action more in NC than in C. If this occurs, then it is predicted that children will replicate contra-lateral arm movements more often in NC than in C. So in both object- and body-related actions children were expected to copy the distinctive action style more in NC than in C, because children will infer movement-based goals more in NC than C.

Each imitation task was introduced with a novel label (e.g., "wubsing") to decrease children's focus on external goals and to ensure that they would pay attention to all elements of an action sequence (e.g. Keupp et al., 2013). The British Picture Vocabulary Scale (2nd edition) was also administered to children as previous research found a close connection between imitation and communication skills (De Giacomo et al., 2009; Stone, Ousley, & Littleford, 1997).

Another variable that has been argued to affect children's imitation of other people's actions is their perspective-taking abilities. According to Perner and Doherty (2005) one can understand actions as either goal-oriented (as done to bring about an effect in the world) or as goal-directed (where one understands that the action is done by an agent who has that goal in mind); the latter understanding requires a grasp of intentions and a certain level of mind-reading. The GOADI account (Wohlschläger et al., 2003) would argue that children understand actions as goal-directed, whereas I have argued in Chapter 1 that most findings in children's imitation can be explained using a goal-oriented understanding. Thus, if movement-based goals can be understood without a grasp of intentions, then this provide evidence that pre-schoolers can understand movement-based goals without needing to understand that the model had that goal in mind (as an intention). To assess whether children's perspective-taking abilities was related to their imitation accuracy I administered a false belief task (Perner, Mauer, & Hildebrand, 2011; Wimmer & Perner, 1983). The false belief task was chosen as it is an assessment of children's grasp of other people's mental states, and children typically pass the standard version of this task around the age range we were testing (between 3 and 5 years). This would determine whether children who can reason about mental states in the false belief task are more able to infer movement-based goals.

METHODS

Participants. In total 30 children (M_{age}= 47 months, SD = 12 months) participated in the study. The children were split into two age groups: 2- to 3-year-olds (N = 15, 7 male, M_{age} = 38 months, SD = 5 months, range: 26 – 47 months), and 4- to 5-year-olds (N = 15, 6 male, M_{age} = 56 months, SD = 8 months, range: 48 – 70 months). The catchment areas for the schools, playgroups and nurseries differed socio-economically, however this variable was not analysed in this study. All parents gave written consent prior to their children participating in the study and debrief forms were provided. Ethical approval was granted by the Psychology Ethics Committee of the University of Stirling.

Materials. Children were given four object tasks (see Table 1A)**,** each consisting of toys custom-made for the study. Children were also shown four body tasks (see Table 1B), consisting of everyday actions chosen based on previous studies (Gleissner et al., 2000; Stone et al., 1997; Zmyj, Aschersleben, Prinz, & Daum, 2012). Table 1 details the materials and actions involved in each of the tasks of Study 6 and Study 7. Children's verbal mental age was assessed using the BPVS-II flipchart. Their perspective-taking abilities were assessed using a standard false belief task (Perner et al., 2011; Wimmer & Perner, 1983) presented on a laptop.

Table 4. Descriptions of the actions and materials for the object games in Studies 6 and 7

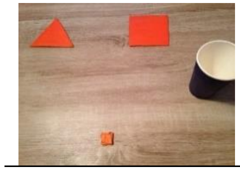
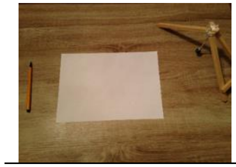
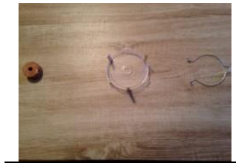
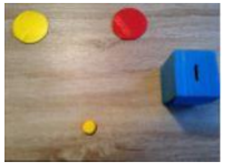
Game	*Materials*	*Action 1*	*Action 1 movement style*	*Action 2*
Gilbing / Filling the cup 	Both conditions: cut-out shapes of triangles and squares, a cup. C condition only: a larger triangle and square	C condition: moving the cut-outs from their pile to their corresponding shape NC condition: moving the cut-outs to unmarked places on the table	Zigzagging the shapes across the table towards the locations	Placing the cut-outs into the cup
Teebing / Ringing the bell 	Both conditions: bell in a wooden tripod C condition only: a piece of A4 paper and a pen NC condition only: no paper and a stick replaces the pen	C condition: drawing a circle on the paper with the pen NC condition: moving the stick around in a circle on the table	Dragging the pen/stick across the table	Ringing the bell with the pen
Yemsing / Threading the beads onto the wire necklace 	Both conditions: wooden beads and a wire necklace C condition only: three plastic prongs	C condition: placing the wooden beads onto each of the prongs in a circle NC condition: hopping the bead around in a circle	Sliding the wooden beads across the table on their side	Threading the beads onto the wire necklace
Wubsing / Slotting the coins into the box 	Both conditions: set of red and yellow coins and a slotted box C condition only: larger red and yellow circles	C condition: sorting the coins by colour onto the corresponding shape NC condition: moving the coins onto the unmarked locations	Jumping the coins across the table in a hopping motion	Slotting the coins into the box

Table 5. Descriptions of the actions for the body games in Studies 6 and 7.

Game	*Action 1*	*Action 1 movement style*	*Action 2*
Qulling / Rubbing hands	C condition: scratching one's face NC condition: moving one's hand up to one's face	Holding one's hand in a claw-like position	Rubbing one's hands
Lupping / Squeezing your nose	C condition: patting one's head NC condition: moving one's hand up and down above one's head	Raising the arm from the front to the back till it is raised above the head	Squeezing one's nose
Zerping / Clapping hands	C condition: rubbing one's shoulders NC condition: moving one's arms up and down above one's shoulders	Holding one's arms contralaterally	Clapping one's hands
Daxing / Rubbing tummy	C condition: rubbing one's earlobes NC condition: rubbing one's fingers together above one's ears	Using both arms	Rubbing one's tummy

Design. Each child participated in eight tasks: four object tasks in which the actions were performed on objects, and four body tasks, in which the actions were performed on one's own body. To introduce each game we used novel labels, for example "lupping" or "wubsing". The most important factor, which varied within subjects, was the context in which the action was presented: In the context-present condition (C) movements (e.g. hopping coins) had a clear external goal (slotting into the box), while in the context-absent condition (NC) the coins were hopped towards a pre-defined, unmarked location on the table. Overall each child saw two NC object tasks, two NC body tasks, two C object tasks and two C body tasks. The order of task type (body tasks first versus object tasks first) was counterbalanced between children. The order of C and NC was counterbalanced using a Latin Square Design. The British Picture Vocabulary Scale was administered between the body and the object task sets. The false belief task was administered at the end of the session.

Procedure. Each child was tested individually in a separate room from the playgroup/nursery.

Body tasks. For the body tasks the experimenter said: "Now I am going to show you something - this is how I lupp". In C she presented the action in a clear context, such as rubbing one's shoulders, whilst in NC the context was absent. Instead of rubbing one's shoulders the model moved her arms up to shoulder height and moved her hands in a rubbing motion, but did not touch her shoulders. After demonstrating the actions the experimenter said "Now I will show you again" before demonstrating the action a second time. Then she said "One more time" before demonstrating the action a third time. All three demonstrations were performed in less than 30 seconds.

In both C and NC the action had a specific movement style. This was a particular way of performing the action: for example, the experimenter crossed her arms. This movement style was identical in C and NC. After the three demonstrations, the experimenter said to the child: "That was how I lupp. Now it's your turn to lupp". The child was given 30 seconds to imitate the gestures. The same procedure was repeated for all body tasks.

Object tasks. For the object tasks the experimenter began by saying: "Now I am going to show you something - this is how I wubs". The experimenter demonstrated the action with a specific movement style (e.g. hopping). In C the action had a clear context, such as slotting coins into a box, whereas in NC the same movement was used without such a context: The coins were hopped towards a pre-defined, unmarked location. After the first demonstration the experimenter reset the apparatus and repeated the demonstration two more times using the same procedure as for the body tasks.

British Picture Vocabulary Scale (BPVS). The BPVS-II edition flipchart was used as a measure of children's verbal mental age. The experimenter said "Now I'm going to show you some pictures" and then read the standardised instructions as well as the demonstration and practice round.

False Belief Task. A false belief task was presented on a laptop as a PowerPoint animation, while the story was narrated by the experimenter (Perner et al., 2011). The animation showed a girl named Lisa putting her teddy into a red basket and then leaving the room. Whilst she was out her brother, Tom, moved the bear from the red basket to the yellow basket and then left. Once the room was empty the child was asked some comprehension questions to check their understanding of the story. If they answered any of these incorrectly the story was repeated. Lisa was then shown re-entering the room and the child was told that she wanted to play with her teddy, asking the child "Where will Lisa search *first* for her teddy?" Then Lisa was shown how she in fact looked in the red basket and the child was asked "Why did Lisa search for her teddy in the red basket?"

Coding. If the child performed the movement style (e.g. jumping the coin; crossing arms contra-laterally) they would receive a score of 1, and if they did not replicate the movement style they would get a score of 0. Children were coded by the experimenter during the testing sessions.

To calculate children's verbal mental age scores, we followed the guidelines of the BPVS-II handbook.

For the false belief task answering the prediction question "Where will Lisa search first for her teddy?" with "red" would score the child one point, while "yellow" would score zero. The child's answer for "Why did Lisa search for her teddy in the red basket?" was given full points (2 points) if it made explicit mention of mental states, e.g. "Lisa *thought* it was still in there" or "she *didn't know*". Whereas an answer that gave a relevant story fact, such as "she put it there", would be given 1 point. If the child replied with irrelevant story facts, such as "it's in the yellow basket", or desires, such as "she wanted to look there", the child would score zero (Perner, Lang, & Kloo, 2002; Priewasser, Roessler, & Perner, 2013). For the purpose of analysis this was added to the first score to get a total out of three.

RESULTS

Preliminary Analyses. There was no effect of task type order (object tasks first vs. body tasks first) on body or object movement style imitation, all *ps* > .33. There was also no effect of context order (C first vs. NC first), all *ps* > .51. Girls and boys imitated at similar rates on all scores, all *ps* > .18. These variables were not considered further.

Movement Style Imitation. A mixed factorial repeated-measures ANOVA was conducted on the imitation style scores (e.g. hopping) for task type (object vs. body) and context (C vs. NC) with age group (2 levels: 2- to 3-year-olds and 4- to 5-year-olds) as between subject factor. As seen in Figure 10 context significantly affected movement style imitation, $F(1, 28) = 24.03$, $p < .001$, η^2=.46. As predicted children imitated movement style more faithfully in NC (M = 1.53, SE = .10) than in C (M = 0.87, SE = .13). Children also imitated movement style more faithfully on the object tasks (M = 1.42, SE = .10) than on the body tasks, (M = 0.98, SE = .13), $F(1, 28) = 11.21$, $p = .002$, partial η^2=.29, although the difference between body and object task imitation was smaller in C (M_{diff} = 0.28) than in NC (M_{diff} = 0.60), $F(1, 28) = 4.80$, $p = .037$, partial η^2=.15. The older age group (M = 1.43, SE = .13) also imitated movement style more faithfully than the younger children (M = 0.97, SE = .13), $F(1, 28) = 6.61$, $p = .016$, partial η^2=.19. 9 In passing it can be noted that children imitated the action end goal of the action sequences at equal rates regardless of condition.

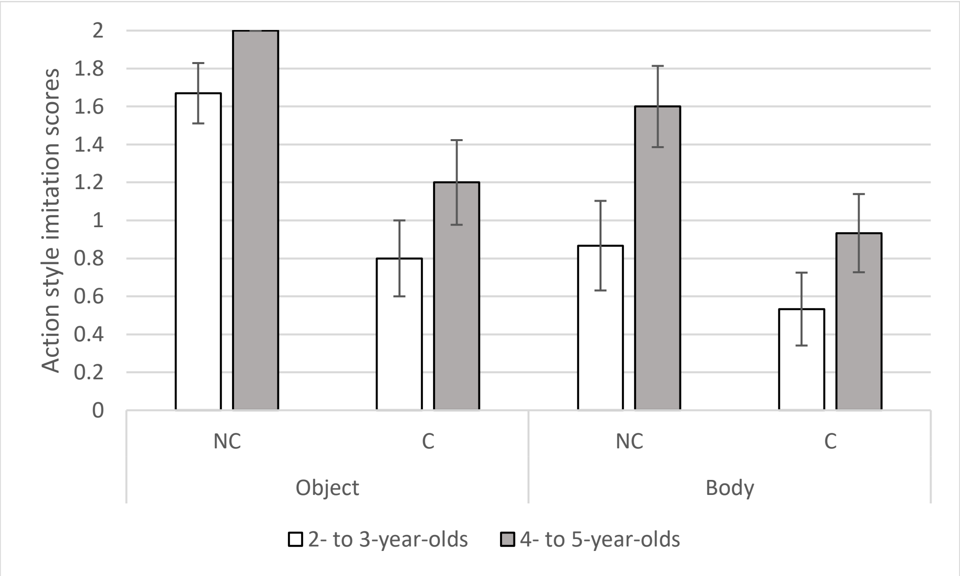


Figure 10. Movement style imitation scores split for context-present (C) and context-absent (NC) condition for both age groups. Bars indicate standard errors.

Upon entering children's BPVS raw score as a covariate the main effect of context (C vs. NC), $F(1, 27) = .674$, $p = .42$ and its interaction with task type (body vs object), $F(1, 27) = 2.34$, $p = .14$, fell below significance. When controlling for false-belief understanding, the main effect of task type was marginally significant, $F(1, 25) = 3.90$, $p = .059$, while its interaction with context fell below significance, $F(1, 25) = 1.82$, $p = .19$. The main effects of age group and context remained significant.

DISCUSSION

The prime objective of Study 6 was to replicate findings that children reproduce different elements of an action sequence depending on the context (Bekkering et al., 2000; Carpenter et al., 2005; Gleissner et al., 2000). Consistent with previous studies, children copied movement styles (e.g., hopping) more accurately when an external goal was absent. Another finding was that children with greater verbal ability imitated the model's body movements more faithfully than children with lower verbal ability. A link between language skills and imitation of body movements has been previously found (De Giacomo et al., 2009; Stone et al., 1997) and was interpreted in terms of children's communicative development. Before children can verbally express their needs and desires, they use their body to communicate and convey information (Nadel & Fontaine, 1989; Nadel, 2002; 2014). Only gradually do they swap gestures for words which may explain the close link between body movements and verbal abilities.

Movement styles were copied with greater accuracy in the object tasks than in body tasks, which is also in line with previous studies (Christie & Slaughter, 2009; Kim et al., 2015; Stone et al., 1997). Kim et al. (2015) found this difference even when the actions involved were identical between body and object tasks. Salient external effects (e.g. pushing a button causes a light to turn on) increased object-related imitation in their study. In the present study too, object movements produced a salient effect (tapping coins on the table), which could explain why they were copied with increased accuracy. Salient target objects may also direct children's attention to the observed action, facilitating action encoding and retrieval (Elsner, 2007). Indeed, even infants remember actions associated with objects (Bhatt & Rovee-Collier, 1996; Borovsky & Rovee-Collier, 1990; see Paulus, 2014) and they reproduce observed actions with said objects when given the chance (Yang, Bushnell, Buchanan & Sobel, 2013).

False-belief understanding had no effect on the difference between NC and C – this suggests that children's ability to infer movement-based goals was unrelated to their perspective-taking abilities. This could be taken as evidence that children understand movement-based goals in the goal-oriented sense, rather than the goal-directed sense which would require an understanding of that agent has having that goal in mind. Whereas GOADI would argue that imitation and goal understanding require a grasp of intentions, generalist theories would claim that intentions are not always necessary to imitate. The current findings support this latter view, as movement-based goal inference was unrelated to false-belief understanding in Study 6.

Finally, there is converging evidence that over the course of development children copy actions more faithfully, particularly when those actions do not lead to an obvious external goal (Hilbrink et al., 2013; Marsh et al., 2014; McGuigan et al., 2011; Nielsen & Tomaselli, 2010; Nielsen, 2006; Xu & Kushnir, 2013). In the present study too, with increasing age children copied movement styles more accurately in body and object tasks. Thus, Study 6 fully replicates several previous findings, providing a good foundation to investigate the primary aim of this chapter: whether children would still imitate arbitrary actions if they were presented as fulfilling a second external goal rather than a movement-based goal.

Bekkering et al. (2000) speculated that the inability to track multiple goals may limit action imitation in younger children. If, as Schachner & Carey (2013) propose, arbitrary actions are interpreted as movement-based goals and movement-based goals are ranked lower in the hierarchy of goals (Baker, Saxe, & Tenenbaum, 2009), then younger children in particular, who may only be able to track one goal, would be more inclined to imitate external goals. This would explain the difference in infants' imitative performance for actions with/without context: In C they infer an external goal (i.e., slotting coins) while in NC, due to the lack of an external goal, they infer a movement-based goal (i.e., hopping), giving rise to selective imitation. If infants observe an action sequence which leads to a clear effect, they will be most likely to imitate actions that led to that effect and omit arbitrary actions that did not lead to that effect (as was found by Brugger et al., 2007). As children's cognitive capacities become more powerful, they may be able to consider both types of goals, giving rise to faithful imitation of arbitrary actions. In Study 7 therefore the number of external goals in the model's action sequence was increased from one to two, to see whether this would affect the difference between C and NC in any of the age groups.

STUDY 7

Previous studies have shown that children copy actions more faithfully when they are performed without context (i.e. when no plausible goal can be attributed to the action). Study 7 investigated whether this would still be the case when, rather than appearing as simply arbitrary, actions had a secondary external goal unrelated to the main external goal of the task. This is important as it establishes whether there is a difference between cases where the movements can be related to clearly different external goals, and cases where there is only one external goal, but the movements achieve it in a clearly inefficient way (as is the case in over-imitation studies, e.g.: Horner & Whiten, 2005; Keupp et al., 2013; Nielsen & Blank, 2011). If children are more likely to infer movement-based goals in the latter case (when there is only one external goal) then it would provide evidence that arbitrary actions are interpreted as movement-based goals in over-imitation studies.

Study 7 used the same games and set-up as Study 6. To investigate whether the number of goals would affect movement style imitation an extra external goal was added in both NC and C. In C in the object tasks for instance the coins were hopped towards colour-matched plates, before being slotted into the box. In this case, it was possible to extract two external goals, (1) sorting coins onto plates and (2) slotting coins into a box. In NC the coins were hopped towards a blank, predefined location, but they were eventually slotted into a box. Importantly the hopping action was never directed towards the box, but to the side away from the box such that the movement style did not directly lead to the external goal of slotting. While in NC the hopping action did not directly lead to an external goal, in C the coins were sorted onto colour-matched plates, thus building a context around the hopping movement.

NC of Study 7 closely resembles classic over-imitation tasks, which typically include an action (hopping coins towards pre-defined locations) that does not have an observable effect on the end-goal (slotting coins into a box). As Schachner and Carey (2013) pointed out, movement-based goals should also be inferred for arbitrary actions when they bring about an external goal in a clearly inefficient way. If this is indeed the case, children in Study 7 should imitate movement-styles (e.g., hopping) more faithfully in NC than in C. In contrast, if particularly younger children, like infants (Hauf, Elsner, & Aschersleben, 2004), prefer to copy actions with salient effects (e.g., slotting coins), then they should imitate the movement style (hopping) at equal rates in both conditions.

In Study 6, children imitated the end goal of the action sequences at equal rates between the NC and C conditions. However, now that there were two actions demonstrated by the model in C, it was possible that children would not imitate the actual end goal of the action as much as in NC. Therefore in addition to recording children's imitation of movement styles, children's actual reproduction of the end goals was recorded.

Study 7 also looked at the effect of labels on children's imitation pattern. Previously, Herrmann et al. (2013), revealed that imitative fidelity of 3- to 6-year-olds was lower when they stated the end-goal (e.g. "she gets pegs up"), in comparison to a convention-oriented condition ("she always does it this way"). Keupp et al. (2013) investigated this effect further by either naming the game after its effect (e.g. "ringing the bells") or with a novel label (e.g. "daxing"). In their study, children protested against the omission of arbitrary actions more in the novel label condition. Thus, framing the game in terms of a novel label encouraged children to pay attention to actions that were not causal in bringing about the final goal. Elsner and Pfeifer (2012) also observed that pre-schoolers were more likely to reproduce an action's end goal at the expense of copying the model's movement faithfully if that end goal was verbally emphasised by the model. In Chapter 3 of this thesis, labelling was not found to have an effect on children's imitation in a successive-models task. Given these mixed findings, labelling was included as a variable in this study to see if it would affect imitation on a different type of copying task. In the present study the model either called the task by its end-state (e.g., "slotting the coin into the box") or by a novel label (e.g., "wubsing") to see whether this affected movement style imitation. Given the effects found in Study 6 the BPVS-II and the false belief task were also included.

METHODS

Participants. Participants were 58 children aged between 31 and 71 months (M_{age} = 49 months, *SD* = 11 months) from British nurseries, playgroups and schools. An additional child was excluded due to uncooperativeness. Children were randomly assigned to either the novel frame (*N* = 30, 12 males, M_{age} = 48 months *SD* = 10 months *range*: 31 - 67 months) or the end-state frame (*N* = 28, 16 males, M_{age} = 50 months *SD* = 11 months *range*: 34 – 71 months).The final sample was split into two age groups: children aged 2 to 3 years (*N* = 29, 15 males, M_{age} = 40 months; *SD* = 5 months, *range*: 31 - 48 months) and children aged 4 to 5 years (*N* = 29, 14 males, M_{age} = 58 months *SD* = 7 months, *range*: 48 – 71 months). The catchment areas for the schools, playgroups and nurseries differed socio-economically, however this variable was not coded in this study. All parents gave written consent, debrief forms were provided after the study and the procedure was approved by the Psychology Ethics Committee of the University of Stirling.

Materials. Study 7 used the same materials as Study 6. Additional custom-made materials were used for the new external goal (e.g., coloured plates). Table 1 details the materials and actions involved in each of the tasks. Children's verbal mental age was assessed using the British Picture Vocabulary Scale (second edition) flipchart and their perspective taking abilities were assessed with a standard false belief task (Wimmer & Perner, 1983).

Design. As in Study 6 each child participated in four object tasks and four body tasks. One group of children received the tasks using novel names, for example "lupping" or "wubsing", while the other group received the tasks naming the effect of the last action in the sequence, for example "clapping your hands" or "slotting coins into the box". Context type, context-present (C) and context-absent (NC), was again varied within subjects, so each child saw two NC object tasks, two NC body tasks, two C object tasks and two C body tasks. The order of task type (body tasks first versus object tasks first) was counterbalanced between children. The order of context (C vs NC) was counterbalanced using a Latin Square Design. The British Picture Vocabulary Scale was administered between the body and object task sets and the false belief task was administered at the end of the session.

Procedure. Each child was tested individually in a separate room from the playgroup/nursery.

Body tasks. For the body tasks the experimenter said: "Now I am going to show you something - this is how I lupp/clap my hands". The experimenter then demonstrated the same body actions as in Study 1, but finished with an additional external goal, for example, by clapping the hands.

Object tasks. For the object tasks the experimenter began by saying: "Now I am going to show you something - this is how I wubs/slot the coins into the box". The experimenter then performed an action with a specific movement style (e.g. hopping). In C the first action had a clear context, such as sorting coloured coins onto corresponding coloured plates, whereas in NC the same sequence of movements was used without such a context (e.g. the plates were absent). In both conditions the coins were finally slotted into the box.

Coding. Children were coded on whether they imitated the final action (e.g., sorting) in each task. Children could receive three possible scores. If they brought about the goal, they received a score of 1; if they did not, they received a score of 0. If they attempted the goal but did not complete it they received a score of .5. Scores were coded separately for body tasks and object tasks and could range between 0 and 4 (as there were four body and four object tasks each). Children were also assessed on whether they imitated the specific movement style. If children performed the movement style for the action in question they received a score of 1; if they did not perform the movement style they received a score of 0. Scores were again coded separately for object and body tasks, so for each type of task children received a movement style imitation score that could range from 0 to 4.

RESULTS

***Preliminary analyses*.** There was no effect of gender, context order or game order (the order in which the individual games appeared) on imitation scores, all *ps* > .19. Consequently, these variables were not considered further.

***External goal imitation*.** A mixed factorial repeated-measures ANOVA was conducted on the external goal imitation scores for each task type (object vs. body) and context (C vs. NC) with age group (2 levels: 2- to 3-year-olds and 4- to 5-year-olds) and verbal frame (2 levels: novel vs. end-state) as between subject factors. There was a statistically significant main effect of task type, $F(1, 54) = 16.68$, $p < .001$, partial η^2=.24. As can be seen in Figure 11A, children produced the external goal (i.e., sorting coins) demonstrated by the model more on the object tasks ($M = 1.89$, $SE = .03$) than on the body tasks ($M = 1.51$, $SE = .09$). There was however no main effect of context type or age group for the imitation of the external goal.

However, age interacted significantly with context. While older children ($M = 1.74$, $SE = .07$) did not differ from the younger children ($M = 1.71$, $SE = .07$) in NC, in C older children ($M = 1.78$, $SE = .08$) imitated more accurately than their younger peers ($M = 1.58$, $SE = .08$), $F(1, 54) = 4.12$, $p = .047$, partial η^2=.071. There was also an interaction between action type (body vs object) and context, $F(1, 54) = 4.46$, $p = .039$, partial η^2=.076: on the object tasks the younger children copied the action more faithfully in NC ($M = 1.93$, $SE = .041$) than in C ($M = 1.67$, $SE = .1$), but there was no such difference on the body tasks. No other interactions were significant, *p*s > .21.

Figure 11A.

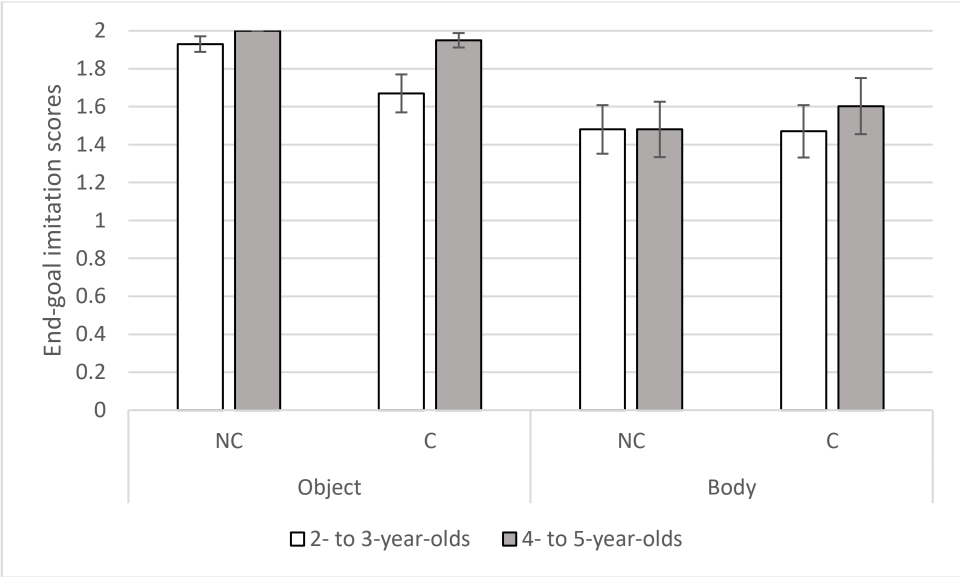


Figure 11B

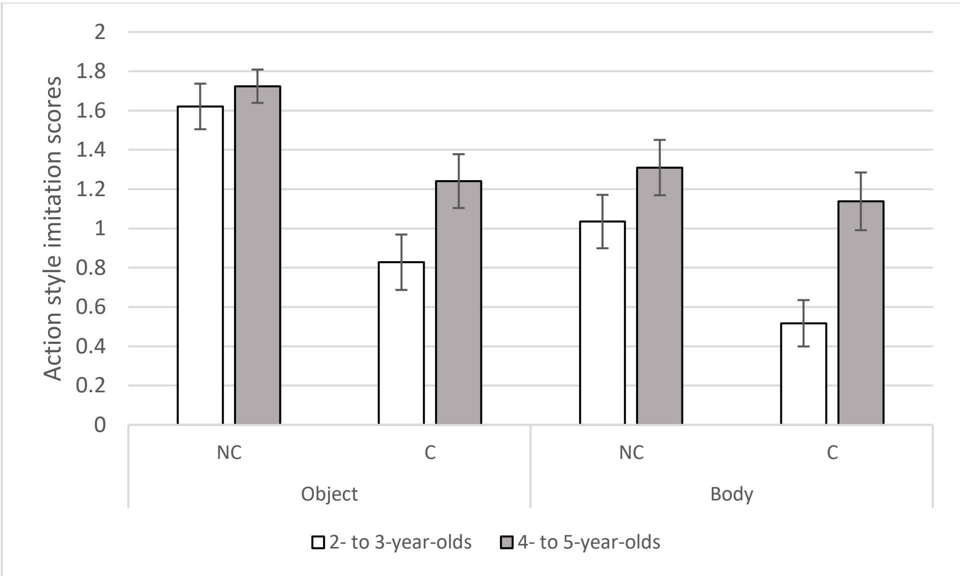


Figure 11. Imitation scores split for context-present (C) and context-absent (NC) condition for both age groups. 11A: End-goal imitation scores. 11B: Movement style imitation scores. Bars indicate standard errors.

Movement style imitation. A mixed factorial repeated-measures ANOVA was conducted on the movement style scores (e.g., hopping) for task type (object vs. body) and context (present vs. absent) with age group (2 levels: 2- to 3-year-olds and 4- to 5-year-olds) and verbal frame (2 levels: novel vs. end-state) as between subject factors. Replicating Study 6, movement style was imitated more faithfully in NC (M = 1.42, SE = .07) than in C (M = 0.93, SE = .07), F(1, 54) = 43.73, p < .001, η^2=.45. So when the secondary action appeared to have an unrelated external goal (in the C condition) children imitated that action significantly less than when it appeared to have no plausible external goal (in the NC condition). Movement style imitation was also greater for object tasks (M = 1.35, SE = .06) than for body tasks (M = 1.00, SE = .09), F(1, 54) = 11.23, p = .001, partial η^2=.17 (see Figure 11B). Older children (M = 1.35, SE = .08) imitated more accurately than the younger children (M = 0.99, SE = .08), F(1, 54) = 10.17, p = .002, partial η^2=.16. There was no effect of verbal frame, F(1, 54) = .19, p = .67. These findings replicated those of Study 6, and the effects can be seen in Figure 10B.

When BPVS scores were entered as a covariate into the above analysis, only the effect of task type fell below significance, p = .253. All other effects remained significant, ps < .05. When false-belief task scores were entered as a covariate all effects remained significant, all ps < .043. This replicates the finding from Study 6 that false-belief understanding was not related to children's imitation of specific movement styles.

DISCUSSION

The aim of Study 7 was to investigate whether preschool-aged children would still copy particular movement styles more accurately when the movements in question finished with an external goal (i.e., slotting coins) that was unrelated to that action, as opposed to when the movement styles had a primary external goal (i.e., sorting coins onto plates) additionally to the other unrelated goal. Overall, children copied movement styles (e.g., hopping), but not end-goals (e.g., sorting coins vs. hopping coins towards an unmarked location), more accurately in the context-absent condition than in the context-present condition.

This supports Schachner & Carey's (2013) hypothesis that arbitrary actions can be interpreted as having movement-based goals. Movement-based goals will be inferred when movements do not have an external effect on the environment or when actions only bring about goals in clearly inefficient ways. In Study 7, hopping the coins towards colour-matched plates could be interpreted as an external goal (i.e. sorting the coins onto the plates) which was unrelated to the other external goal of slotting the coins into the box. In this case then children should not infer a movement-based goal for the model's actions of hopping the coins and will instead infer that this action is for a primary external goal. In the context-absent condition, however, hopping the coins towards unmarked locations did not appear to have a direct external goal. However, it could be viewed as bringing about the external goal of slotting the coins into the box in a very inefficient way. Under such circumstances, children are more likely to interpret the movement style as being done for the movement's sake and led to children copying the movement style more faithfully when it was performed without context.

The type of verbal frame did not affect children's imitation of movement styles or external goals. In previous studies children protested more against the omission of arbitrary actions when the task was framed with a novel name (Keupp et al., 2013) and they showed higher imitation fidelity under this condition (Herrmann et al., 2013). Based on this it was predicted that children in NC (most closely resembling previous tasks) would copy the hopping action more often when the task was framed with a novel label, because using the end-state frame should highlight the final goal of the action sequence. Keupp et al. (2013), albeit finding a difference in children's protest, also did not report a difference in imitation fidelity, which is in line with our data. However, their result could have been caused by a ceiling effect in imitation fidelity overall and as such no definitive conclusion can be drawn.

A very stable effect was found between object- and body-related actions. Movement styles were copied with higher accuracy in the object tasks than in the body tasks. This has been found previously (Christie & Slaughter, 2009; Kim et al., 2015; Stone et al., 1997; Taneguchi & Sanefuji, 2017). Gibson's theory of affordances (Gibson, 1986) would suggest that objects trigger the action previously associated with them, while the body does not have such an effect. Leighton et al. (2010) have proposed that certain body-movements are perceptually opaque—observing such movements and executing them result in different sensory input, whereas performing movements on objects yield similar sensory effects for observation and execution. It may be that differences in sensory input caused children to copy body movements less accurately.

Leighton et al. (2010) have also argued that different visual cues could cause children to imitate differently in NC and C. Indeed, while in C the coins were hopped towards a box (Study 6) or coloured plates (Study 7), in NC the coins were hopped towards unmarked locations in both studies. Generalist accounts of imitation (such as the ASL model, Catmur et al., 2009) would argue that imitation in NC may be enhanced because there are less visual cues distracting children from the model's actual movement. Thus, removing these cues results in increased imitation fidelity, instead of children viewing the movement as a goal in itself. Moreover Kim et al. (2015) suggest an object could act as an external cue to what one is supposed to do (e.g., a box with a slit may trigger slotting). To isolate the effect of such visual cues on children's imitation the results of the C condition of Study 6 and NC of Study 7 were statistically compared. Both conditions had the same amount of objects present during the demonstrations (e.g. a box visible on the table) but while in Study 7 the actions were directed away from the end goal in question (e.g. coins were hopped towards an unmarked location before being slotted in the box) in Study 6 the actions always were directed towards the end goal (e.g. the coins were directly hopped towards the box rather than away from it).

COMPARISON OF STUDY 6 AND STUDY 7

The two conditions that were compared were the novel label frame NC condition of Study 7 and the C condition of Study 6. Both were identical in terms of the materials involved and the labels used however there is an important difference: In C of Study 6, the actions were directed towards the end goal of the action sequence, making the specific action style appear inefficient. For example the coins were hopped along the table towards the box, before being slotted in. The hopping may appear inefficient to the goal of slotting the coin, and may thus be copied less frequently. The NC condition of Study7 has a very different feel: here the actions are first directed away from the end goal, before eventually completing the end goal. For example the coin is hopped away from the box, to be then taken (without hopping) and slotted into the box. From an adult perspective it would seem more likely to infer a movement-based goal in this condition as the action appears disconnected from the external goal: hopping seems more important if the coins are being hopped away from the box than if they are being hopped towards it. Hence, if children reproduced the movement style more frequently in Study 7 than in Study 6, this would weaken the idea that the difference between C and NC is simply caused by differences in visual cues.

Participants. The comparison used the data of the children allocated to the novel label NC condition of Study 7 (N = 30, 15 males, M_{age} = 48 months; SD = 10 months, *range*: 31 – 67 months) and the C condition of Study 6 (N = 30, 13 male, M_{age} = 47 months, SD = 12 months, range: 26 – 70 months). Children's mean age was not significantly different between the two Studies, $t(58)$ = .24, p = .81.

Results. A mixed factorial repeated-measures ANOVA was conducted on the imitation style scores for task type (object vs. body) with age group (2 levels: 2- to 3-year-olds and 4- to 5-year-olds) and Study (Study 6 vs. Study 7) as between subject factors. As predicted, children in the NC condition (M = 1.48, SE = .11) of Study 7 imitated movement style more faithfully than children in the C condition (M = .87, SE = .11) of Study 6, $F(1, 56) = 15.51$, $p < .001$, η^2=.22. When the model demonstrated an action that could not easily be associated with the end goal of the action sequence, children imitated that action more faithfully than when the action could be easily associated with the end goal of the action sequence. When controlling for verbal ability, the main effect of Study remained highly significant, $F(1, 51) = 12.38$, $p < .001$, η^2=.20. The same mixed factorial repeated-measures ANOVA conducted on external goal imitation scores did not find a main effect of Study, $F(1, 56) = 2.58$, $p = .11$, meaning that children demonstrated end-goals at similar rates between the different studies. These results suggest that, despite identical visual cues, children copied movement styles more faithfully when they were less efficient in bringing about the external goal.

GENERAL DISCUSSION

The most important finding from this chapter is that children copied movement styles more accurately when said movements did not lead directly, or not at all, to an external goal. Most compellingly, children copied movement styles more accurately in NC of Study 7, when the coins were sorted to unmarked locations before being slotted, than in C of Study 6, in which the coins were directly hopped towards and slotted into the box. Despite an identical set-up children's imitation differed between the two conditions. In line with Schachner and Carey's (2013) analysis it appears that children infer movement-based goals particularly in cases in which movements are arbitrary or not functional in bringing about an external goal. This finding suggests that cases of high-fidelity imitation or "over-imitation", in which children copy clearly arbitrary actions, could be cases of movement-based goal emulation (Horner & Whiten, 2005; Keupp et al., 2013; McGuigan & Graham, 2010; McGuigan et al., 2011; Moraru et al., 2016; Nielsen & Blank, 2011; Whiten et al., 2016).

Previously, such findings of context-dependent imitation have been taken to support goal-directed theories of imitation (Bekkering et al., 2000; Gattis, Bekkering, & Wohlschläger, 2002; Gleissner et al., 2000). According to such theories when we observe actions we extract action characteristics, whereby—due to capacity limitations—more attention is given to the goal of an action, more than to the precise movements involved. The selected action goals subsequently elicit motor programmes with which they are most strongly connected (Hommel, 2009). Some of these motor programmes, but not all, match the observed movements: when the goal of an action is extracted, this can lead to selective imitation of the precise movements used by the model, if that model had used unusual actions to achieve a known goal. Action sequences for which clear goals can be extracted are typically copied with less exact fidelity then action sequences for which the goal is ambiguous. This is because familiar goals have known motor programmes which bias one's imitation of said goals (Gampe et al., 2015) and identifying the goal of an action sequence increases the likelihood of ignoring the specific movements used (Froese & Leavens, 2014). Conversely it is when we do not understand the aim of an action sequence, there can be no motor programme associated with the goal and thus we are more likely to imitate faithfully.

The findings from Studies 6 and 7 would suggest that goal inference can indeed have an effect on children's imitation fidelity. However an important caveat is that movement-based goal inference may only be possible for pre-schoolers. Previous research has shown that infants tend to focus on reproducing salient end goals (Kim et al., 2015), and show more faithful imitation of end states over arbitrary actions (Jones, 2007; Brugger et al., 2007). They may therefore be unable to infer movement-based goals under the age of 3 years. The current studies show that by pre-school age children infer movement-based goals about actions, and will replicate the same action more or less faithfully depending on the type of goal they associate with the model. Movement-based goals encourage faithful imitation of all aspects of an action, as the movement is an integral part of the action's goal (Schachner & Carey, 2013).

The findings of Chapter 4 suggest that imitation in pre-schoolers is affected by their goal understanding. However the literature review covered in Chapter 1 would stress that this does not mean that goal inference is a necessary step in imitation. For example the associative sequence learning (ASL) model (Bird et al., 2007; Leighton et al., 2010), assumes a direct link between sensory and motor representations of actions. What is being imitated depends on general processes related to attention, memory and perception, such as to which parts of the object attention is drawn to (Huang, Heyes, & Charman, 2002; Mizuguchi et al., 2011). Similarly, ideomotor theories do not assume that imitation necessitates the ascription of intentions or goals to somebody else. Instead, by perceiving another person's action, one's own motor system is activated, which in turn activates associated action representations that direct one's attention to the relevant information (Paulus, 2012b). Such theories are supported by findings showing that children's action understanding and imitation is affected by their own action experience (Paulus et al., 2011; Hunnius & Bekkering, 2014).

Taken together, psychologists are discordant whether children conceive of actions as goal-directed during imitation (i.e., they understand that the modeller had a goal in mind; in other words, that the modeller acted intentionally) or whether they view these actions as merely goal-oriented (i.e., they represent the external goal without an understanding that goals can be represented internally; see Perner & Doherty, 2005, for this distinction). In interpreting the data of the current chapter, I argue for a goal-oriented interpretation of imitation such that children in these studies were trying to figure out what the goal of the task was, but they did not ascribe these goals to the modeller.

The reasons for this conclusion are twofold: *Firstly,* the results from Studies 6 and 7 show that children's performance on the false belief task minimally affected the results, suggesting that children did not take the modeller's perspective when they imitated. In essence, they did not infer what the modeller's intentions were or what goals this person had in mind when observing their actions. *Secondly,* Roessler and Perner (2015) show that during the second year of life children start to display various forms of pro-social behaviours such as helping and comforting. Interestingly, it is around this time (14 months) that infants begin to imitate arbitrary actions (Brugger et al., 2007; Hauf et al., 2004; Jones, 2007). This move from a focus on reproducing only actions with causal effects to reproducing seemingly pointless actions may indicate children's growing understanding of actions being done for a good reason.

Roessler and Perner argue that there is a close connection "between the reasoning involved in understanding others' actions and the reasoning involved in deciding what to do" (p. 763). Children's ability to understand what other people are doing (grasping the goals of tasks) thus helps them direct their own action. On Schwier et al.'s task (2006), whether the child has good reasons to copy the dog going through the chimney depends on whether children believe there was a good reason to put the dog through the chimney. If the door was open for the adult's demonstration, the child will naturally assume that going through the chimney is the proper way of doing this task. If the door was locked for the adult, but open on the child's turn, then the adult's way of doing this task does not apply to the child. In other words, children may take certain features of a situation to provide them with reasons to act. Such an understanding does not require an understanding of others' mental states: children merely need to understand people as doing things for reasons which then may or may not apply to themselves. Very young children particularly focus on the end-state, while pre-schoolers' growing action experience with situations where movements are themselves the goal of other's actions (Hunnius & Bekkering, 2014) means that they see reasons in reproducing movement styles accurately. This is further supported by Mizuguchi et al. (2011) who show that by 4 years children's imitation does not focus solely on end states but can be modulated to focus on specific movements.

Children not only develop the ability to infer movement-based goals with age, they also appear to emulate such goals more throughout the pre-school years. As mentioned above children imitate arbitrary actions by the age of 4 years (Kenward et al., 2011) and do so more with age (Marsh et al., 2014). Replicating a movement-based goal could indicate a growing motivation on the child's part to affiliate with the model. Supporting evidence for this comes from Nielsen et al. (2015): in their study 4-year-olds saw a model demonstrate how to retrieve a toy from a box, including arbitrary actions in their demonstration. Children reproduced the arbitrary actions most when directly imitating the present model, and least when they were helping a different model who wanted to retrieve the toy from the box. This effect was heightened when the arbitrary actions had been demonstrated to the child *after* the box was open, highlighting their inefficiency towards the goal of "opening the box". Four-year-olds can thus modulate their imitation depending on whether they want to perform an external effect (retrieve a toy) or copy the present model faithfully. Replicating arbitrary actions can thus indicate a growing motivation for children to affiliate with the present model.

One potential limitation in Study 4 which could weaken support for the idea that movement-based goals are viewed in a goal-oriented manner is the possibility that the false belief task is not the best way to assess children's intention understanding. While false belief understanding may be an indicator of the ability to understand that people have incorrect mental states, intentions are specific mental states which may be understood at a different time than false belief. For instance, Lang and Perner (2002) administered the knee-jerk task to 3- to 5-year-olds as a measure of intention understanding. Children would watch as somebody would tap their knee with a toy hammer and, when their leg kicked, were asked "Look, your leg moved! Did you mean to do this?". The youngest children in this study mistakenly answered that they had indeed meant to kick their leg, and success on this task (answering "no") was associated with both age and success on a standard false-belief task. The knee-jerk task may therefore be a more valid assessment of children's intention understanding, and could be used to confirm whether movement-based goals can be inferred without an understanding of intentions. This is something that would be useful to investigate in the future.

The findings from Chapter 4 can be compared with the results observed from Chapters 2 and 3. In these chapters even 3-year-olds imitated arbitrary actions if they were demonstrated by M1, showing that by this age children copy actions even if they do not have salient effects. Thus, children by the age of 3 years do not require salient action effects to imitate, presumably because they begin to infer that the goal of an action is the movement itself. This would fit with data from Moraru et al. (2016) who find that when 3-year-olds observe a model demonstrate actions saying "I will show you how to get the toy out", they copy these actions more faithfully than if the model says "I will show you one way to get the toy out". Cues to the conventionality of an action may encourage the inference of a movement-based goal for that action. Wilks et al. (2016) highlight that one of the characteristics of ritualistic action is that it is redundant and arbitrary. Therefore if an action has no salient external effect, children are more likely to infer that the action in question has some conventional status (leading to more faithful imitation of that action). Not all movement-based goals will necessarily be interpreted as conventions, but movement-based goals seem to form part of ritualistic and conventional action.

It should be noted that verbal cues signalling conventionality did not enhance imitation in children above 4 years in Moraru et al.'s study (2016). Similarly in the current study labelling had no effect on encouraging faithful imitation in 3- to 5-year-olds. What this may suggest is that, as children age, they require less of a reason to imitate a model's movement-based goals and arbitrary actions (Marsh et al., 2014). As mentioned in Chapter 2 children get better at imitating multiple models with age – and as I have argued above, one reason for this increase may be that children become more socially motivated to reproduce a model's actions with age, and part of this change may be an increasing tendency to copy the movement-based goals of actions.

In conclusion, this chapter argues that children copy movement styles more accurately (a) when movements do not bring about an external goal (in comparison to when an external goal is brought about) and (b) when movements are clearly an inefficient means to bring about an external goal. This difference is unlikely driven by low-level perceptual features such as the amount of visual information, but appears to be based on movement-based goal inference for actions that are not causal or functional to an intended outcome. This finding expands current attempts to make sense of “overimitation” by providing preliminary evidence that high-fidelity imitation of arbitrary actions may be an instance of movement-based goal emulation.

CHAPTER 5

SUMMARY OF THE PREVIOUS LITERATURE

The actual processes of action reproduction are low-level, in that they do not involve complex cognitive reasoning: perceived actions are associated with specific motor programs through experience and associative learning (Paulus, 2012, 2014; Brass & Heyes, 2005; Catmur et al., 2009). Once this association is formed, observing a movement’s effect will prime reproduction of the same movement. Imitation can be modulated by highlighting different parts of the action to be reproduced (Bird et al., 2007; Leighton et al., 2010; Mizuguchi et al., 2011) and is constrained by children’s own action experience (Hunnius & Bekkering, 2014; Gampe et al., 2015; Paulus et al., 2011). It is therefore not necessary to posit the existence of a specialist, goal-inferring mechanism required for all instances of imitation (Meltzoff, 1995; Wohlschläger et al., 2003). Imitation can be automatic, feature-driven without consideration of the goal of an action sequence.

There are nevertheless cases where imitation is goal-oriented (Perner & Doherty, 2005). If the goal of an action is emphasised by the model during their demonstration, pre-schoolers will prefer to reproduce this goal over the exact movements used by the model (Elsner & Pfeifer, 2012). If no verbal or conventional cues emphasise the goal of the action, children and adults show no preference for copying goals over movements (Leighton et al., 2010; Mizuguchi et al., 2011). Goals therefore can affect imitation: in particular if a goal state is highlighted (by verbal, visible or conventional cues) then imitation of that goal will be prioritised over the precise means involved. This fits with Froese and Leavens’ (2014) model of direct perception, which argues that intentional actions are primarily evaluated in terms of their goals. Attributing a goal to an action sequence means that if the learner desires to bring about the same goal as the model, they will focus on reproducing this goal rather than copying the model’s exact movements.

As children age imitation gradually comes to be used for more than merely replicating effects produced by the model. During the second year of life children begin to copy irrelevant actions (Jones, 2007) and also to spontaneously imitate peers in parallel play situations (Nadel & Fontaine, 1989). Five-year-olds' imitation can also be heightened by the threat of social exclusion (Over & Carpenter, 2009) suggesting that by this age imitation may serve a social function of affiliating with a model (Chartrand & Bargh, 1999). Imitation can be used to indicate likeness with a model or a social group and therefore has social consequences beyond reproducing an action's external effects (Nadel, 2002, 2014). Whereas children will prefer to reproduce object-directed actions with external effects by the age of 18 months, social consequences do not seem to become important reinforcers for imitating actions until after this age (Kim et al., 2015). Therefore the social function of imitation, as a tool to foster interaction and liking, may begin to be in place after the age of 2 years.

MAIN GOAL OF THE THESIS

Previous literature has shown that imitation, whilst not essentially goal-related, is affected by children's inferences of action goals under specific circumstances. It is still however unclear how children's interpretation of goals changes with age. The few studies that investigated imitation development throughout childhood (Marsh et al., 2014; McGuigan et al., 2011; Moraru et al., 2016) found children's imitation of arbitrary actions increases with age. The main aim of this thesis was (a) to review the literature on imitation, in particular, high-fidelity imitation (chapter 1), (b) to investigate how high-fidelity imitation changes throughout childhood (chapter 2) and (c) to extract factors that explain this change (chapters 3 and 4). Chapter 3 particularly focussed on factors to explain perseverative imitation in young children such as misunderstanding that two different actions can be given the same label, inhibitory deficits, model identity and object affordances. Chapter 4 focussed on the question of whether children perceive arbitrary actions in the context of movement-based goals. Schachner and Carey (2013) have shown that when observing actions performed without context, adults are more likely to assume that the actions themselves were the goal of the model. I investigated whether children's action imitation changed depending on the type of goal that could be attributed to a model's actions.

FINDINGS FROM THE CHAPTERS

One of the primary aims of this thesis was to investigate how children's interpretations of model actions changed with age. A useful paradigm for assessing this question has been the successive-models paradigm (Keupp et al., 2013, 2016; Nielsen & Blank, 2011) where children observe two models, M1 and M2, demonstrate different ways of performing the same task. Children's reactions to M2 (i.e. whether they will copy them as much as M1, whether they protest against them) reveals whether they felt they could deviate from M1's actions. However previous successive-models studies have only looked at children under 5 years. Therefore in Chapter 2 I ran a successive-models paradigm with children aged 2 to 12 years to see how they reacted to multiple models throughout childhood, and how this affected their imitation. Children over 6 years had a tendency to copy whichever model was present (displaying "model-dependent imitation") and this increased with age, reaching ceiling performance at age 10. Children under 5 years copied M2 less often than M1 and children under 3 years in particular showed a strong tendency to perseverate with M1's actions and would not deviate from them, thus showing "perseverative imitation".

In Chapter 3 I controlled for a number of different factors to explain why children under 5 years did not copy each model in turn as older children would. Previous work has suggested that children's use of labels may be rather inflexible, and they do not like hearing two models use the same word to describe different things (Brandl et al., 2015; Markman et al., 2003; Casler, 2014). This is why I hypothesised that when M1 and M2 were using the same label, particularly children under 4 years would not accept M2's action once they had seen M1's action being demonstrated with that label. Unlike adults, children's imitation was however not affected by whether M1 and M2 used the same or a different label for their actions. Similarly, when M1 and M2 did not use any label for their actions, children's imitation was unaffected.

Another hypothesis for why young children may have shown "perseverative imitation" was that they would lack the inhibitory strength to refrain from exercising an action for which they had motor experience. Previous research indicated that children's imitation is affected by their own action experience (Hunnius & Bekkering, 2014; Paulus, 2014) and children have difficulty imitating actions that are not in their own motor repertoire (Gampe et al., 2015; Paulus et al., 2011). To control for this, children either copied the two models directly after each trial, or they only watched the two models before they had a go themselves. Additionally, children's inhibitory skills were assessed with a Bear/Dragon task, to investigate if inhibitory skills may interact with children's motor experience. Indeed, children with greater inhibitory ability were better at omitting arbitrary actions performed by M1 thus going along with M2's shorter action sequences. As expected, inhibitory ability had no effect when children had simply observed M1 and M2. Inhibition skills thus affected imitation when children had motor experience, but only for omitting an action. When adding an action, children at different inhibitory levels showed similar performance, indicating that inhibitory control is only relevant when a child wants to refrain from copying a previously copied action. This explains partially why younger children may have perseverated on copying M1, particularly when M1 had demonstrated the arbitrary action. It does, however, not explain why particularly young children did not add an action when M2 demonstrated the arbitrary action, as adding an action does not utilise inhibitory control.

Study 4 therefore looked at whether children's imitation of M2 could be affected by the identity of M2. In previous successive-models paradigms M2 tended to be a puppet to encourage children to protest against any deviation (Rakoczy et al., 2008; Keupp et al., 2013). However children are more disposed to copy certain types of models – one such bias is that adults tend to be seen as more reliable than children (Schmidt et al., 2011; Wood, Kendal & Flynn, 2013a). I therefore conducted a study using a successive-models paradigm, where one model was a puppet and the other was an adult. Children preferentially imitated the actions demonstrated by the adult, and this effect heightened their imitation of M2 (if M2 was the adult) or reduced it (if M2 was the puppet), suggesting that particularly young children tend to follow the first model's demonstration if the second model, who is demonstrating the same game slightly differently, is not as trustworthy.

In the final study of Chapter 3 I investigated whether not only the type of model but also the use of the same objects would affect children's imitation. Pre-schoolers can associate objects as being "for" certain actions and purposes (Casler & Kelemen, 2005; Greeno, 1994). If children see an object used for a certain action, they will remember the action associated with that object, and the object becomes a cue for remembering that action (Paulus, 2012b). However, children are also capable of associating actions with certain people: Nielsen and Blank (2011) conducted a successive-models task where 4-year-olds saw two models demonstrate different actions on the same object. The children would imitate a model's action sequence more faithfully if that model was present, showing that they remembered which action sequence was demonstrated by either model. The aim was to see how children would imitate if these two cues (object and model) were associated with different actions. Three- to 5-year-olds saw two models, M1 and M2, demonstrate two action sequences which they both called by the same name to create the same context. However the two models displayed their actions on two differently-coloured versions of the same apparatus. Children observed the two models (without imitating, to avoid an interaction with the motor experience effect isolated in Study 3) and were then asked to play the game by one of the models. Sometimes the model was present with her own object or with the other model's object. Of interest was, whether children, would be affected by the object-model discrepancy, or whether they would show similar levels of imitation in any the conditions. In the discrepant cases, if children pay attention to the object, they have to decide whether to reproduce the action performed by the present model, or whether to use the object the way they have seen it used before. The main result was that children under 5 years would imitate a model's actions most faithfully when that model was present with their own object. When the model and the object had displayed different actions, children's imitation was reduced. But when the two cues were associated with different actions children did not have a preference for copying either action, indicating that children under 5 years are equally influenced by both the presence of a model and the actions used with an object.

In short, Chapters 2 and 3 showed that children's imitation of multiple models increases in fidelity with age. One factor affecting this development was children's motor inhibition, but only when children had to omit actions they had previously performed themselves. Another factor was the type of model: children preferred to copy adults over puppets and trustworthy models enhance children's ability to omit previously performed actions. Moreover, preschool-aged children did not prefer to reproduce actions associated with models over those associated with objects. Indeed, when faced with a dilemma, either by the models using the same object (Studies 1 to 4) or whether the present model used the object demonstrated by the other model (Study 5) children were at chance as to what action sequence to use. It was only later in childhood, after around 6 years, that children imitated the present model faithfully after seeing the two action sequences (Study 1). The younger children thus may have viewed the task about learning to perform different action sequences, whereas as children age they may become more likely to automatically assume they need to imitate the present model.

As seen above children's goals in successive-models tasks change with age, with the goal of copying the present model becoming more important above the age of 6 years. However an open question from Chapters 2 and 3 is whether it is possible to modulate children's imitation by varying the type of goal children associate with the model's actions. Schachner and Carey (2013) argue that adults are more likely to assume that an action is demonstrated for its own sake if it is performed without any context or with no observable effect. Adults infer "movement-based goals" (e.g. dancing, ritual) when actions are performed without any visible context, and Schachner and Carey (2013) suggest that this may also encourage high-fidelity imitation. To see whether actions would be copied more faithfully by children if no obvious goal could be associated with them was the goal of Chapter 4. Pre-schoolers were shown a model demonstrate actions either within a context that pointed to a clear goal (e.g. slot the coins into the box) or with no such contextual cues. The children imitated actions more faithfully when the actions had no clear goal than when there was an obvious goal. In Study 7 I increased the number of goals so now the model's actions either had context that could be interpreted as two distinct goals (hop the coins onto the plates > slot them into the box) or context indicating only one goal (hop the coins away from the box > slot them in to the box). The children imitated the model's actions more faithfully when they could not be attributed to a plausible, secondary goal that is when they were performed without context. This effect was still present when the visual information was the same between the context and no-context conditions: the same amount of objects and actions was present, the only difference was whether the actions could be associated to the same goal or not. Thus children's imitation of a model's actions is affected by the goals that can be attributed to those actions and high-fidelity imitation is encouraged in pre-schoolers by suggesting that actions have movement-based goals (i.e. by performing them with no context).

RELATING FINDINGS TO PREVIOUS LITERATURE

The thesis highlights several findings that contribute to previous research. Successive-models paradigms have previously been used to investigate how children understand the actions of models and how this affects their imitation, but this type of task has not been used beyond pre-school age (Rakoczy et al., 2008; Keupp et al., 2013; Nielsen & Blank, 2011). Chapters 2 supplemented this gap by investigating how children imitated successive-models between the ages of 2 and 12 years. Children began to imitate both models faithfully by the age of 6 years, but below this age children would either perseverate on the first model's action (regardless of whether this included an arbitrary action) or they would add an arbitrary action to M2's demonstration but not omit it. At the age of 6 years children began to imitate copy the present model on all turns on the task, and this tendency became stronger with age.

These findings show that children under the age of 5 years do not automatically infer the goal of "copy the present model" in the successive-models task used here. However previous studies have shown that children under 5 years can infer the goal of "copy the present model" in other situations: Horner and Whiten (2005) describe that children in pilot testing believed that they needed to copy the present model and wanted to show how well they could copy the experimenter. Similarly Moraru et al. (2016) showed that 4- to 6-year-olds would imitate a model's arbitrary actions regardless of the way the model described their demonstration, whereas 3-year-olds would imitate arbitrary actions more faithfully if the model described these actions using a conventional label ("I will show you *how* you do this…") as opposed to a label without conventional status ("I will show you *one way* to do this…"). Therefore children under 5 years are not incapable of inferring the social goal of "copy the present model", but they do not do so on successive-models tasks. Rather they use either model's solution at chance once they have seen both models do them (as also observed in Wood et al., 2013b). Children under 5 years may view the two models as demonstrating equally viable options – acquiring multiple solutions on a known task can be beneficial by enabling children to build on previous knowledge (Wood et al., 2013b): they may thus have been motivated to learn multiple solutions and thus used them flexibly (as they may have been more interested in learning about the task than copying the present model, Over & Carpenter, 2012). Children do not infer the goal of "copying the present model" for successive-models tasks until above the age of 6 years, and only reliably above the age of 9 years. It may be harder for children to infer such social goals in situations when multiple models are involved.

Chapter 3 showed that children's imitation of a deviant model was related to their inhibitory ability, but only if imitation of that model required children to omit an action they had already performed. Imitation thus requires different abilities depending on the type of behaviour that is to be produced. Gampe et al. (2015) showed that imitation of known actions involves different processes to the imitation of unfamiliar actions, in line with the dual-route model of imitation laid out by Rumiati and Tessari (2002, 2004). Copying another person's actions involves different abilities depending on what needs to be done. Overall this finding sits well with generalist accounts of imitation, such as the IMAIL and ASL accounts (Paulus, 2014; Catmur et al., 2009), as these accounts argue that imitation involves general processes of action control and production. Imitation is thus always imitation of a specific task: how children copy depends on the type of action that is being done. This is supported by the fact that when children do not receive motor experience on a task, they are not primed to reproduce only the first action sequence: in this case model presence seems to be a stronger cue affecting their imitation (Nielsen & Blank, 2011). Successive-models tasks should therefore consider how easily children will be able to imitate the actions of the model; if children have experience imitating a model, it may be more difficult for younger pre-schoolers to omit actions. If children imitate multiple models (rather than merely observe them) then a certain amount of inhibitory ability will be needed for children to be able to copy the different models faithfully.

However Study 4 also showed that imitation in successive-models tasks can be modulated by the presence and identity of the model during the child's turn. Successive-models studies looking at normativity (Rakoczy et al., 2008; Keupp et al., 2016) use puppets as the deviant model who omits part of what the original model did. However children's imitation of a deviant model is dependent on who that model is. Children under 5 years imitate adults more than puppets in a successive-models task (Study 4). This effect countered the inhibition effect observed previously, as children would not inhibit their performance of M1's arbitrary action if M2, leaving it out, was a puppet. Therefore successive-models studies should consider that children may not copy deviant models if they are puppets, whereas they may be more likely to do so if they appear as more reliable than the original model. Future successive-model studies on normativity should thus consider that lower imitation of a deviant model may not be a response to norm violation, but simply due to children's reduced imitation of puppets as opposed to people. Studies that compare the order of the models (for instance by having a silly adult as M1 and a reliable puppet as M2) would be more stringent tests of children's model-based biases and normative understanding.

Model presence also affected children's imitation: Study 5 showed that children were more likely to demonstrate the action sequence demonstrated by the model present during the child's turn. Model presence can also account for why Schleihauf et al. (2017) found that, in a successive-model study, 5-year-olds would not deviate from the initial solution they were shown. In their study the children kept on demonstrating the first action sequence they were shown, but always performed their actions in the absence of any model. In Studies 1 to 5 presented in this thesis, children imitated with the deviant model present. Whilst the 3- to 5-year-olds did not imitate the deviant model as faithfully as M1, children would still imitate M2 to some extent (and became more likely to do so with age), more so than was found by Schleihauf et al. (2017). Nielsen et al. (2015) also showed that pre-schoolers imitated arbitrary actions on a box more in the presence of the model who had demonstrated them initially than when they were helping a third party (who had never seen the arbitrary actions) to open the same box. The current findings thus fit with previous work that social factors such as model presence, interactivity and identity encourage imitation fidelity in pre-schoolers (Nielsen et al., 2008; Nielsen & Blank, 2011; Nielsen et al., 2015; Over &

Carpenter, 2011, 2012; Rakoczy et al., 2010; Wood et al., 2013a). In particular, model presence can help children inhibit previously performed actions. Imitation is thus a composite ability – it is affected by multiple processes (such as sensitivity to model presence, children's own action experience, motor inhibition…) and high-fidelity imitation is thus dependent on the interaction between these factors.

Together Chapters 2 and 3 suggest that low-level factors such as inhibition influence children's imitation. However by pre-school age children's imitation is also affected by other factors that cannot easily be explained without reference to more complex cognitive processes than the action-effect binding processes that form the basis for imitation in infancy (Paulus, 2014). Whilst older children are affected by such factors as motor inhibition, their imitation is also modulated by different factors such as model evaluations, object associations and the combination between the object and the model present on children's turn. Furthermore, the findings from Chapter 4 show that by age 3 years children's imitation is additionally modulated by the type of goal they attribute to the model's actions. If the movement is perceived to be the goal of the action, children will imitate that action more faithfully than if they perceive the action as having a distinct, external goal. Thus goal understanding influences imitation fidelity in pre-schoolers.

As discussed in Chapter 1, the IMAIL and ASL accounts posit that imitation is not necessarily related to goal-understanding, as imitation can occur automatically and be driven by low-level perceptual features (Bird et al., 2007; Leighton et al., 2010; Mizuguchi et al., 2011). However these accounts also stress that imitation can be affected by children's understanding of goals, as goal-inference can modulate the basic action-effect matching processes that develop in infancy (Paulus, 2014; Ray & Heyes, 2011). The findings from the current studies support both the generalist claim that goal inference is not necessarily involved in imitation, as it can instead be explained using basic action control processes, and the idea that imitation is affected by goals under certain circumstances. With regards to this latter claim, I posit that, as argued by Schachner and Carey (2013), high-fidelity imitation in pre-schoolers is an example of movement-based goal inference. Movement-based goals will be inferred for arbitrary actions as they cannot be readily associated to other, external goals (as predicted by the model of direct perception, Froese & Leavens, 2014). When this is the case children will imitate the movements themselves more faithfully, leaving to high-fidelity imitation.

Children’s inferences of goals may also change with age. In particular children seemed to become more likely to infer the goal of copy the present model with age, in the type of successive-models game used here. In accordance with Over and Carpenter’s theory of goals in imitation (2012, 2013) this could suggest that children become more likely to infer social goals in action situations from mid- to late-childhood. This would fit with Marsh et al.’s findings (2014) that children became more likely to imitate arbitrary actions between the ages of 5 and 8 years, and grew more likely to do so even though they grew better at recognising that these actions were arbitrary (which suggests they copied for social reasons, to affiliate with the model). Children’s increased exposure to situations where they are expected to copy (as in school) may thus bias them to imitating models who are seen as reliable without being told to do so. Children become more likely to conform to majorities on ambiguous tasks (where there is no evident right or wrong answer) between the ages of 3 and 10 years (Haun et al., 2013). Whilst imitation is not the same thing as conformity, a growing tendency to align one’s actions with other people may underlie both imitation in dyads and with other groups, as it may be of adaptive benefit (as imitation has been posited to serve as social glue with other individuals, Chartrand & Bargh, 1999). Children’s motivations change with age, as they develop more complex social cognition and gain more experience of social learning situations. Becoming more sensitive to social pressure, and aligning oneself automatically with the actions of one’s counterpart, can therefore be a product of growing social experience which children gain as they age.

LIMITATIONS TO THE PRESENT WORK

The studies described in this thesis have attempted to explain the development of children’s imitation throughout childhood. The work has drawn upon a large amount of literature to design appropriate research questions and provide meaningful data. However there are several limitations to the studies described above which are worth highlighting before conclusions can be drawn.

The choice of games used in these studies was driven by a number of factors. One was to keep actions simple so as to avoid the likelihood of children forgetting part of the action sequences throughout the testing sessions. Another was the presence/absence of arbitrary actions to distinguish between Model 1 and Model 2’s action sequences in Studies 1 to 5. This matches previous work on high-fidelity imitation (Nielsen & Blank, 2011; Keupp et al., 2013; Schleihauf et al., 2017) as it helped determine how children were conceiving of the task in question (as their imitation of arbitrary actions reveals more about their imitation than would their imitation of only functional actions). However it must be pointed out that these choices necessarily limit the conclusions to be drawn from this work.

Firstly the fact that the actions used in Studies 1 to 5 were so simple may have affected children's imitation. Redundancy and repetitiveness are qualities that have been argued to bias children into viewing actions as ritualised (Nielsen et al., 2015) which may give them a normative dimension, affecting the way children imitate (Keupp et al., 2013). The current findings may not generalise to other paradigms where action sequences are more complex and the effect of each action is unclear on the final outcome of the sequence (e.g. Gardiner, 2014). For instance children may show different imitation of successive models if the action sequences used by said models include more steps and are more complex. In such complex cases children may use a copy-all, refine-later strategy where they may isolate the key components of actions over time (Whiten et al., 2009). Nielsen et al.'s (2015) multiple-stance theory may predict that demonstrating more complex actions may lead to a focus on the causal mechanisms involved rather than a reflection on the social implications of one's imitation, which in turn may lead to different copying behaviour. Another common paradigm in imitation research is, rather than to use an arbitrary action to distinguish between models, to provide children with an apparatus upon which can be performed two *equally functional* actions. For example in Horner and Whiten's (2005) box, the bolts covering the lid could either be pushed out or dragged out using the stick, and the door could either be lifted or slid out of the way. The use of two equally functional actions may be an even clearer test of how children react when they are taught two different ways of performing the same task. It would be useful to investigate this in future work and decide how it is that children may react to being asked to imitate two functionally equivalent actions. The main point to take away is that the use of simple, game-like actions in the current thesis means that any discussion of children's imitative abilities will be more related to work on children's understanding of games and their social copying, rather than their pure causal inferences.

A second limitation is the restricted age range investigated in the majority of the thesis. Whilst Study 1 looked at children's imitation between the ages of 2 and 12 years, Studies 2 to 7 focussed on children aged 3 to 5 years. My initial plan at the start of the thesis was to review a larger age range, to determine why children imitated successive models more faithfully after the age of 4 years and more faithfully still after the age of 9 years. However the initial follow-up studies to Study 1 did not provide clear answers to explain children's imitation pattern under the age of 5 years (as labelling did not have much of an effect on imitation, as shown in Studies 2 and 3). I decided to focus on this pre-school age-range as I thought it would be of more value to analyse the factors affecting imitation at one stage in more detail than to examine different ages more superficially (and there is more literature on imitation in the pre-school years). However this does mean that a lot of potential work could be done to clarify the change in imitation that occurred towards late childhood/pre-adolescence. With regards to my thesis, the explanations of imitation in later childhood will necessarily be less in-depth as I did not control for the effect of various factors in a systematic way.

Another limitation in the current thesis that should be mentioned is the fact that all studies used a cross-sectional design. While this type of study allows for greater data collection over a shorter period of time, this does not allow for the analysis of individual children's changes in imitation throughout childhood. Given that the thesis looked at how imitation may change throughout childhood, it is important to recognise that without a longitudinal analysis the conclusions will be limited. For future work longitudinal analyses of imitation would be beneficial to determine how children imitate differently as they age, for example in the manner of the study by Jones (2007) with infants aged between 6 and 20 months.

A final limitation is the absence of video-recording. Whilst the coding procedure always involved multiple coders for Studies 1 to 5, Study 6 and 7 did not include a second coder. The findings from this present research would be made far more reliable if the responses of each child could be recorded and then analysed by naïve coders later on. Given that a crucial variable of interest in Studies 6 and 7 was the style of a particular movement, this behaviour would be able to be analysed in more detail if video recordings were made available. This will be addressed in future work. With these caveats addressed it is now possible to turn to the conclusions that can be drawn from the present work.

CONTRIBUTIONS AND FUTURE RESEARCH QUESTIONS

The current thesis makes several novel contributions to the existing literature on children's imitation, and highlights several directions for future research. Successive-models studies have mainly examined imitation in children under the age of 5 years (Keupp et al., 2013, 2016; Nielsen & Blank, 2011; Rakoczy et al., 2008). Study 1 extends such work by looking at a larger age range, between the ages of 2 and 12 years. Above the age of 10 years children could imitate the different models, whereas children under 5 years did not imitate M2 as faithfully as M1. In the type of game-like tasks used here, the older children easily inferred the goal of "copy the present model" whereas the younger children did not do so. Children under the age of 5 years can infer this goal and imitate models faithfully (as shown by Horner & Whiten, 2005; Moraru et al., 2016), but do not do so with multiple models. Future research should extend these findings by determining under what circumstances children infer the social goal of "copy the present model" and confirm the prediction made here that this goal is inferred more automatically with age.

Chapter 3 produced a systematic investigation of children's imitation of successive models under the age of 5 years, which is an age that has been the focus of a lot of research on imitation. One finding is that, for game-like contexts, labelling does not affect how well children imitated the models, either in the successive-models tasks (Studies 2 and 3) or for a single model (Study 7). The presence of a novel label, or having the models use different labels, did not affect children's imitation. Adults were more likely to imitate both models when they used different labels, but they could have been more sensitive to the implications of the use of separate labels. It is possible that, in children, labels only encourage more faithful imitation of actions when more care is taken to dissociate the salient effect that can be produced on an apparatus from the action referred to with the label (e.g. when the model demonstrates "ringing the bells" and contrasts this with "daxing", see Keupp et al., 2013). In the absence of such prompts children did not automatically imitate actions signalled by novel labels more faithfully than actions without labels.

I have also shown that using a puppet as a model affects children's imitation on successive-models tasks. Children will be more likely to deviate from a known action sequence if the original model is seen as less reliable than the deviant model (e.g. when M1 is a puppet and M2 is an adult, Study 4). They are also less likely to deviate from the original solution if the deviant model is a puppet, suggesting that model evaluations do indeed affect children's imitation in this paradigm. It should be noted that in Study 4 at no point were children told that the puppet was more reliable than the adult, meaning that their tendency to avoid imitating the puppet was not explicitly encouraged by the model. Imitation studies using puppets should therefore consider that children are less inclined to imitate puppets than people, and that this bias may affect children's performance. One possibility is that puppets may encourage children to think of the games as a form of pretence, and children may imitate differently when they are under this assumption.

A consistent finding in Studies 2 to 4 was that the older children were, the more likely they were to copy M2 on the AF_{First} tasks: only the older children in these studies could copy M2 when this involved omitting an arbitrary action they had previously performed when copying M1. Study 3 suggests that this age difference could have been due to children's growing inhibitory skills, but as this was not tested throughout all studies this is still unverified. However this finding does suggest that once children have performed an action one way they struggle to omit the actions they have previously done when doing that same task. Future work on imitation should thus consider whether children will have the inhibitory ability required to copy multiple models. This finding also suggests that if one is attempting to teach something to a child, one should do it correctly, as it may be harder for young children to stop performing actions once they have done them. To avoid forming bad habits pre-schoolers need to be taught something correctly the first time, as it is only when they are older that they will be able to inhibit previously performed actions: in this case, an ounce of prevention is worth a pound of cure.

Another consistent finding in Studies 1 to 4 was that, once having seen two models do different action sequences on the same object, children were at chance as to which action sequence to use (as shown by their scores on $M1_{rep}$). Similarly, if the model and the object present on the child's turn had been associated with different action sequences, children showed no preference for copying either one (Study 5). In both cases, there was a dilemma as to the actions children should perform, caused by either seeing the object manipulated in two ways or by the mismatch between the object and the model. It was only when children were above 6 years that they began to imitate the present model faithfully on every turn, and this only reached ceiling level above the age of 10 years (Study 1). When children under 6 years did not know which of two actions they should do, they performed either one at chance – model presence was only used as the deciding factor by children in mid- to late-childhood. Study 5 showed that for children under 5 years, model presence interacted with the presence of the object to encourage imitation fidelity. The presence of the model thus interacts with other aspects of the learning situation to determine children's imitation.

Chapter 4 supports the idea that goal inference affects children's imitation above the age of 3 years. Pre-schoolers, like adults (Baker et al., 2009; Schachner & Carey, 2013), interpret the actions of others using likely goals, which determines the way they imitate actions. However children's imitation in Studies 6 and 7 was not related to their performance on a false-belief task, suggesting that goal inference was not related to perspective taking.

This supports the argument made by Paulus (2012) that action goals can be inferred without reference to an understanding of intentions. On the whole the findings from Chapter 4 would fit with the idea that children understood the model's actions as goal-oriented without understanding them as goal-directed (Perner & Doherty, 2005). Other work has also drawn this distinction between understanding action goals and understanding intentions: Uithol et al. (2011) argue that while mirror neurons can be used to infer action goals, they cannot be used to infer intentions as this requires abductive reasoning processes beyond the type of one-to-one mapping mirror neurons do. Supporting this, van Overwalle and Baetens (2009) suggest that, neurologically speaking, the action mirroring and mentalising systems are distinct, yet can be used in a complimentary way to understand actions (a similar argument is made by de Lange et al., 2008). Chapter 4 further supports this distinction and also extends this work by showing that mentalising does not appear to be necessary for inferring movement-based goals.

The findings from Chapter 4 could be extended to further explore under what circumstances children infer movement-based goals for actions. Movement-based goals are inferred for actions when these cannot be attributed external goals based upon the context (Froese & Leavens, 2014; Schachner & Carey, 2013). In Study 7, this was done by having actions performed in a distinctive manner before completing an observable goal (e.g. having a coin hop towards a box before being slotted into it). However in this example the action sequence ended by the completion of a goal that seemed plausible given the context: the coin ends up slotted into the box, via a slot that seems purpose-made for that coin. It is unclear what would happen if, in addition to the distinctive hopping motion, the model also ended the action with an unusual goal, for instance by placing the coin on the side of the box instead of slotting it in. In this case, would children infer that the model wanted to place the coin in the box, and do so on their turn? Or would they infer a movement-based goal and replicate the model's movements? Would children finish the plausible goal of slotting the coin – and would they imitate the distinctive hopping style when they did so? Future studies should help clarify how the presence/absence of unusual end goals determine children's inference of movement-based goals and their subsequent imitation (Anderson, 2017, personal communication).

In conclusion, the current thesis has shown that, throughout childhood, imitation is affected by a number of different abilities. Imitation, in line with the claims of IMAIL and ASL, is governed by general processes of action control: the same associative learning that helps infants form links between movements and observed effects governs imitation in later years. Nevertheless, this simple mechanism is affected by other abilities that develop throughout childhood. Imitation comes to be used for more complex social uses that merely mirroring the actions of the model, and children's interpretations of actions, models and the context determines the way they imitate. Imitation is thus a composite ability, involving basic perceptual and higher-order cognitive processes. The sensitivity with which children can imitate is astonishing: the complex way multiple skills combine to produce this phenomenon has made it an absolute pleasure to study over the last few years, and make me excited to continue this research in the future.

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APPENDIX 1: TABLES

Table 1. Materials and actions used for the games in Study 1.

Label - Transparency	*Materials*	*Functional Action (F)*	*Arbitrary Action (A)*
Lopping / Transparent 	A plastic food container, a small dog plush toy, a small wicker basket and a toothbrush.	Opening the container lid with the goal of placing the dog toy in the basket	Brushing the top of the container with the toothbrush
Mooshing / Transparent 	A CD case containing marbles, a small golden ring and a plastic container	Opening the CD case, with the goal of moving a marble into the plastic container	Removing a ring from the centre of the CD case
Trapping - Opaque 	A cardboard box, a small caterpillar toy, a plastic container and some marbles in a green cup	Lifting the caterpillar out of the side of a box with the goal of moving it to the container	Placing a marble in the top hole of the box (into a separate hidden compartment)
Chokking – Opaque 	A big plastic jug, a plastic wand, some marbles in a cup and an additional plastic cup	Placing marbles in the jug with the goal of pouring them into an empty cup	Using the wand to stir the marbles in the jug

Note. Portrayed are the four different games, their names and transparency as well as the respective functional and arbitrary actions.

Table 2. Mean M1, M2 and $M1_{rep}$ imitation scores for all six age groups in both the F_{First} and AF_{First} conditions. Figures in brackets are standard errors.

	Model 1		Model 2		Model 1rep	
	F First	AF First	F First	AF First	F First	AF First
2- to 3-year-olds	2 (0)	2 (0)	.24 (.54)	.12 (.49)	1.94 (.24)	2 (0)
4- to 5-year-olds	2 (0)	2 (0)	1.65 (.79)	.12 (.49)	.41 (.8)	1.88 (.49)
6- to 7-year-olds	2 (0)	2 (0)	1.77 (56)	1.71 (.59)	.82 (.95)	.88 (.99)
8- to 9-year-olds	2 (0)	2 (0)	1.94 (.24)	1.94 (.24)	1 (.91)	1.12 (.93)
10- to 11-year-olds	2 (0)	2 (0)	2 (0)	1.94 (.24)	1.84 (.5)	1.78 (.55)
11- to 12-year-olds	2 (0)	2 (0)	2 (0)	2 (0)	1.88 (.49)	2 (0)

Table 3. Materials and actions used in Study 5.

Name	*Materials*	*Size*	*Functional action*	*Arbitrary action*
Daxing		3 ½ x 3 ½ inches	Turn the object on its side and shake it from side to side, producing a noise	Hold the object upright and move it anti-clockwise in a circle twice
Trepping		3 x 10 inches	Turn the object on its side and shake it from side to side, producing a noise	Rotate the object forward one full turn
Zerping		4 ½ x 4 ½ x 4 ½ inches	Turn on the side light and then the top light	Lift the box and place it on its front, then return to start position
Lobbing		4 ½ x 4 ½ x 4 ½ inches	Press the black switch in and then the white switch in	Tap the right side of the box twice
Mooshing		4 ½ x 3 ½ x 9 inches	Turn the box right side up and open the lid	When the box is on its front, knock the top of the box twice

Table 4. Descriptions of the actions and materials for the object games in Studies 6 and 7

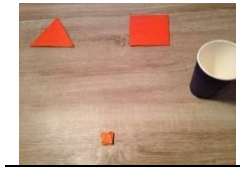
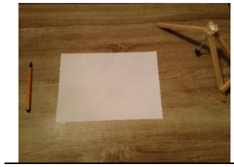
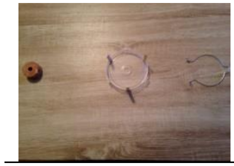
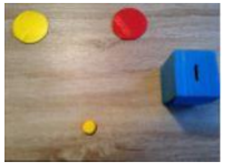
Game	*Materials*	*Action 1*	*Action 1 movement style*	*Action 2*
Gilbing / Filling the cup 	Both conditions: cut-out shapes of triangles and squares, a cup. C condition only: a larger triangle and square	C condition: moving the cut-outs from their pile to their corresponding shape NC condition: moving the cut-outs to unmarked places on the table	Zigzagging the shapes across the table towards the locations	Placing the cut-outs into the cup
Teebing / Ringing the bell 	Both conditions: bell in a wooden tripod C condition only: a piece of A4 paper and a pen NC condition only: no paper and a stick replaces the pen	C condition: drawing a circle on the paper with the pen NC condition: moving the stick around in a circle on the table	Dragging the pen/stick across the table	Ringing the bell with the pen
Yemsing / Threading the beads onto the wire necklace 	Both conditions: wooden beads and a wire necklace C condition only: three plastic prongs	C condition: placing the wooden beads onto each of the prongs in a circle NC condition: hopping the bead around in a circle	Sliding the wooden beads across the table on their side	Threading the beads onto the wire necklace
Wubsing / Slotting the coins into the box 	Both conditions: set of red and yellow coins and a slotted box C condition only: larger red and yellow circles	C condition: sorting the coins by colour onto the corresponding shape NC condition: moving the coins onto the unmarked locations	Jumping the coins across the table in a hopping motion	Slotting the coins into the box

Table 5. Descriptions of the actions for the body games in Studies 6 and 7.

Game	*Action 1*	*Action 1 movement style*	*Action 2*
Qulling / Rubbing hands	C condition: scratching one's face NC condition: moving one's hand up to one's face	Holding one's hand in a claw-like position	Rubbing one's hands
Lupping / Squeezing your nose	C condition: patting one's head NC condition: moving one's hand up and down above one's head	Raising the arm from the front to the back till it is raised above the head	Squeezing one's nose
Zerping / Clapping hands	C condition: rubbing one's shoulders NC condition: moving one's arms up and down above one's shoulders	Holding one's arms contralaterally	Clapping one's hands
Daxing / Rubbing tummy	C condition: rubbing one's earlobes NC condition: rubbing one's fingers together above one's ears	Using both arms	Rubbing one's tummy

APPENDIX 2: FIGURES

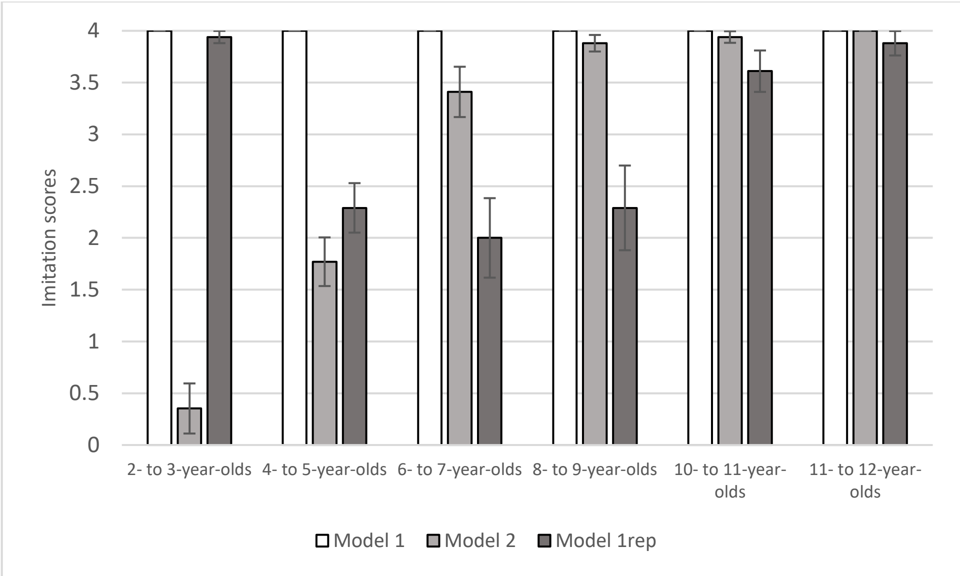


Figure 1. Mean M1, M2 and $M1_{rep}$ imitation scores across all tasks between age groups. Bars indicate standard errors.

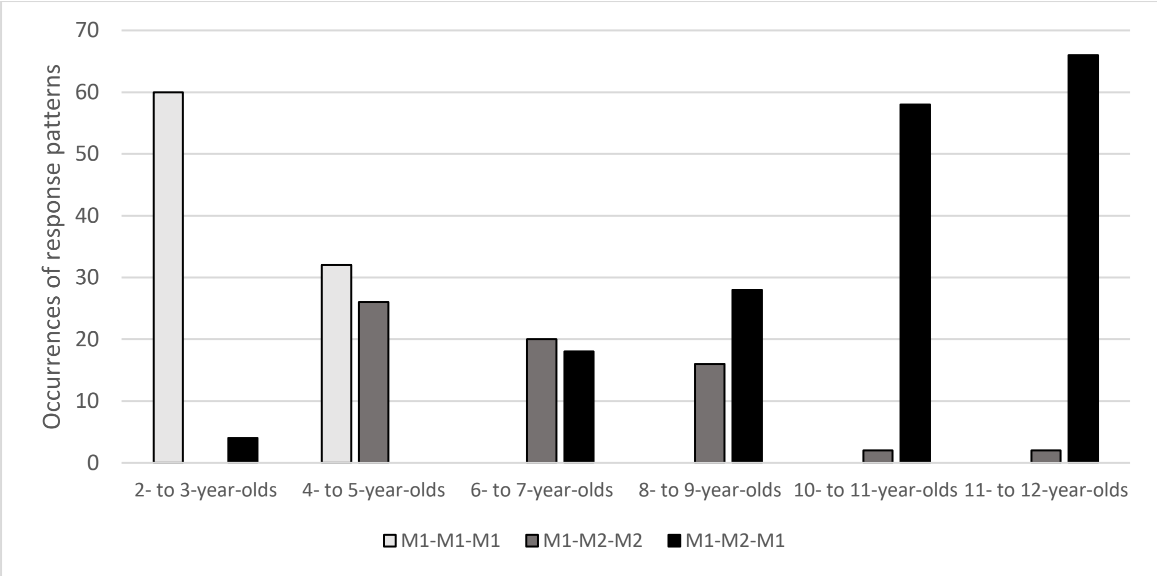


Figure 2. Frequencies for different response patterns occurring in each age group.

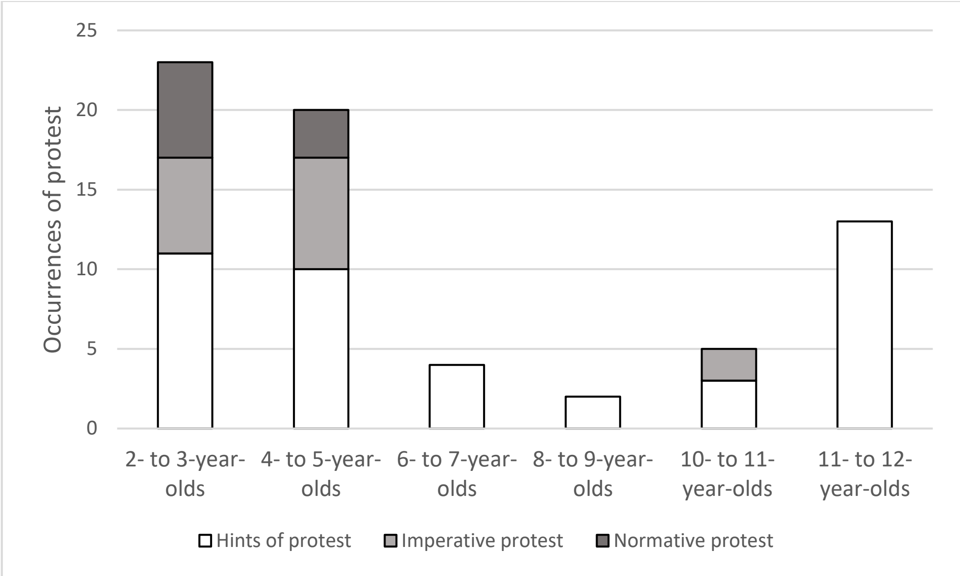


Figure 3. Frequencies of protest occurrences within each age group.

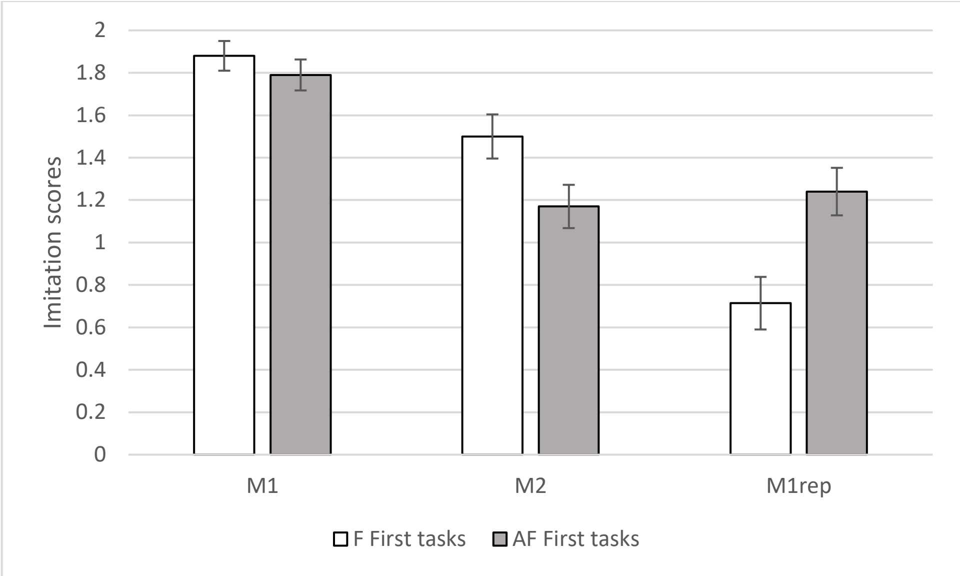


Figure 4. Imitation scores for M1, M2 and $M1_{rep}$ on the F_{First} and AF_{First} tasks. Bars indicate standard errors.

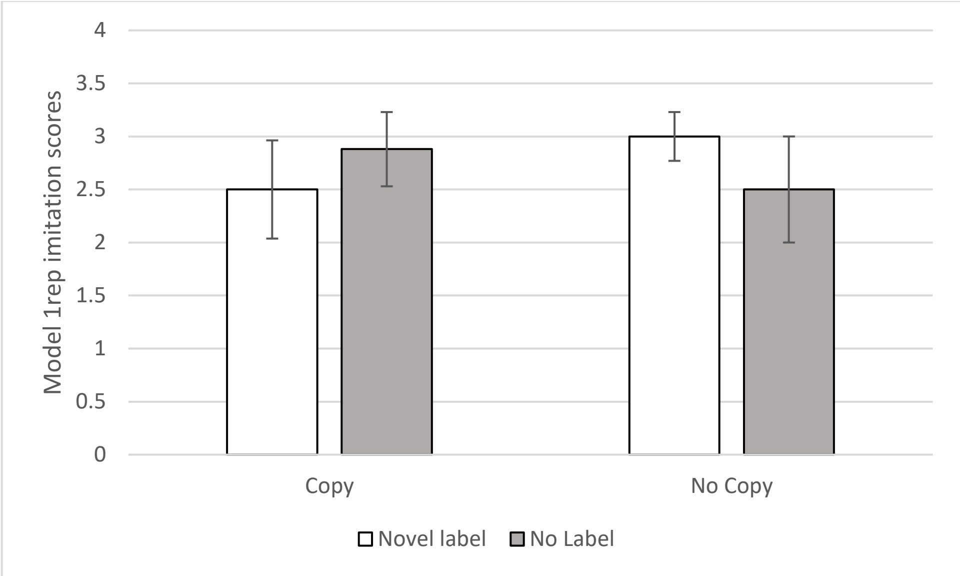


Figure 5. M1$_{rep}$ imitation scores between the four conditions. Bars indicate standard errors.

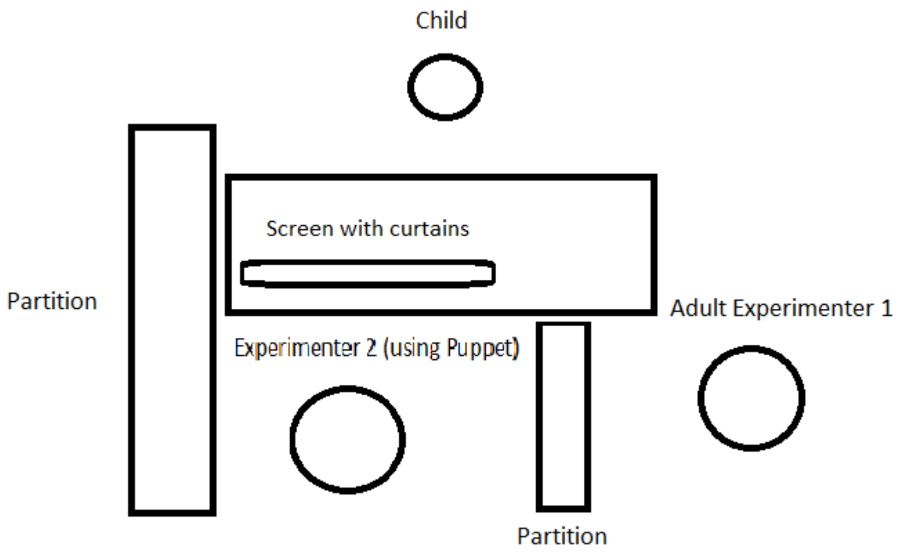


Figure 6. View of the set-up used in Study 4 seen from above.

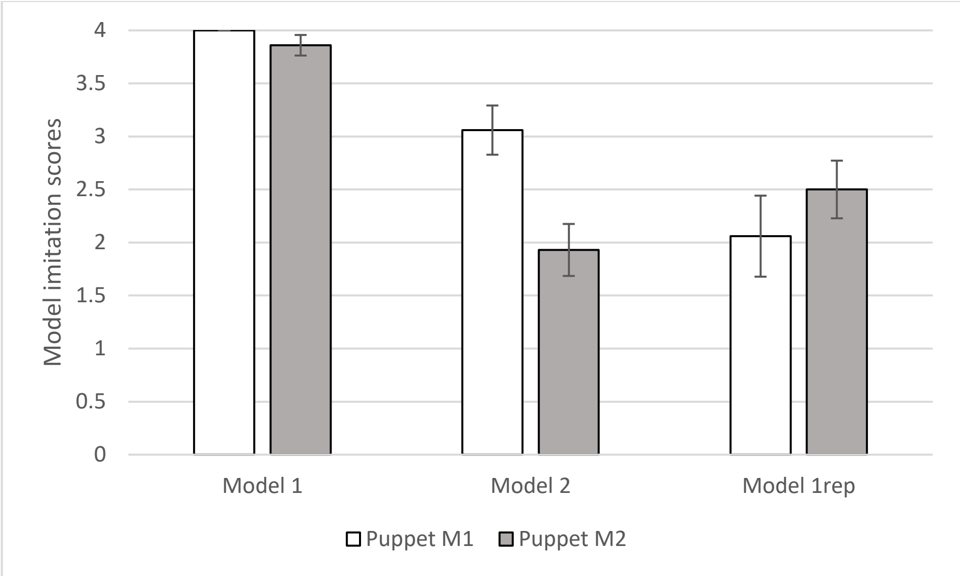


Figure 7. Model imitation scores between the Puppet M1 and Puppet M2 conditions. Bars indicate standard errors.

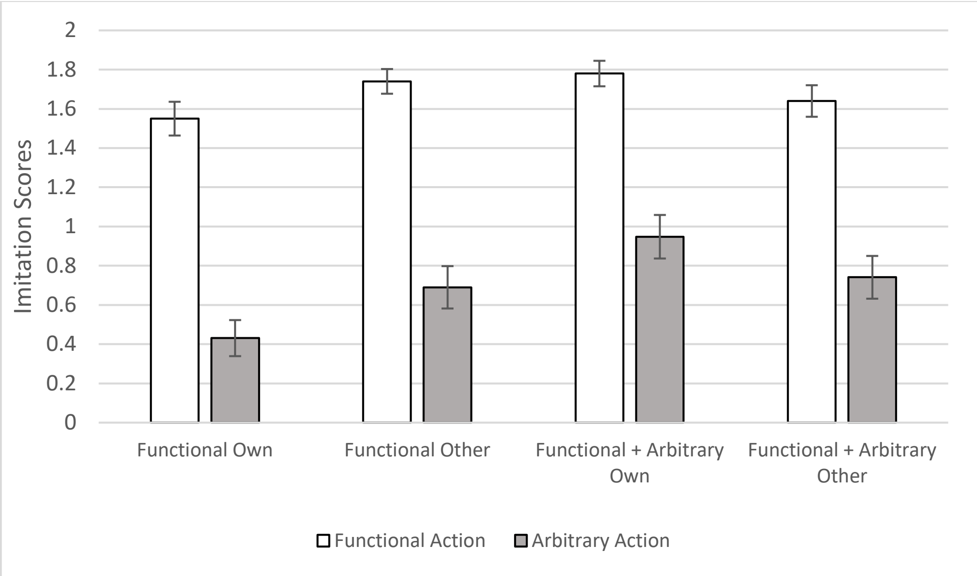


Figure 8. Imitation scores for Functional and Arbitrary actions on the Own and Other tasks. Bars indicate standard errors.

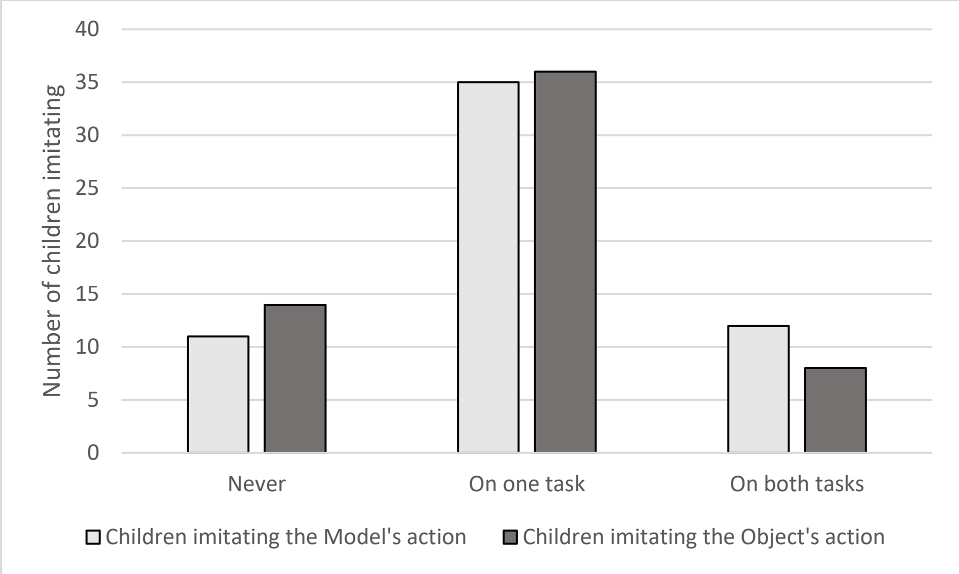


Figure 9. Children's responses on the Other tasks.

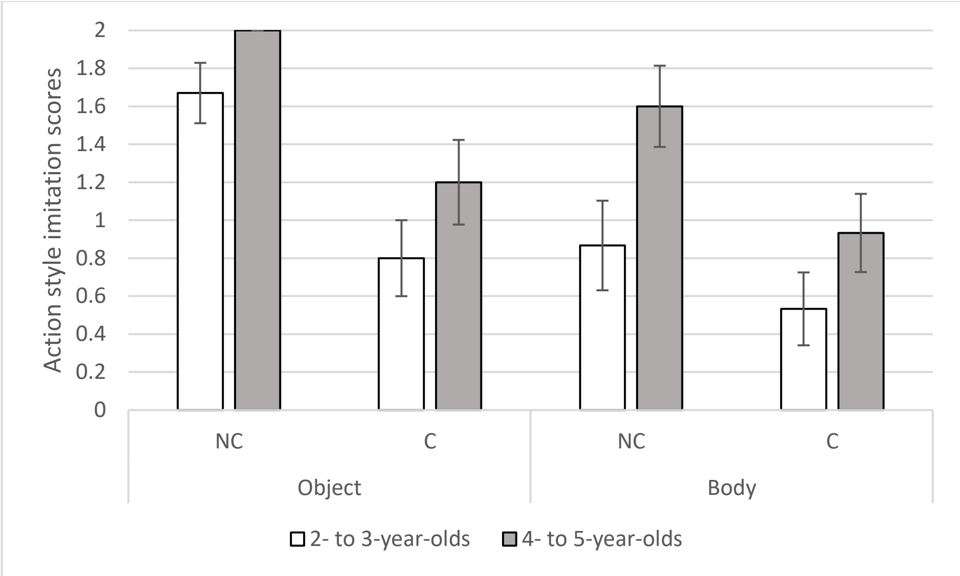


Figure 10. Movement style imitation scores split for context-present (C) and context-absent (NC) condition for both age groups. Bars indicate standard errors.

Figure 11A.

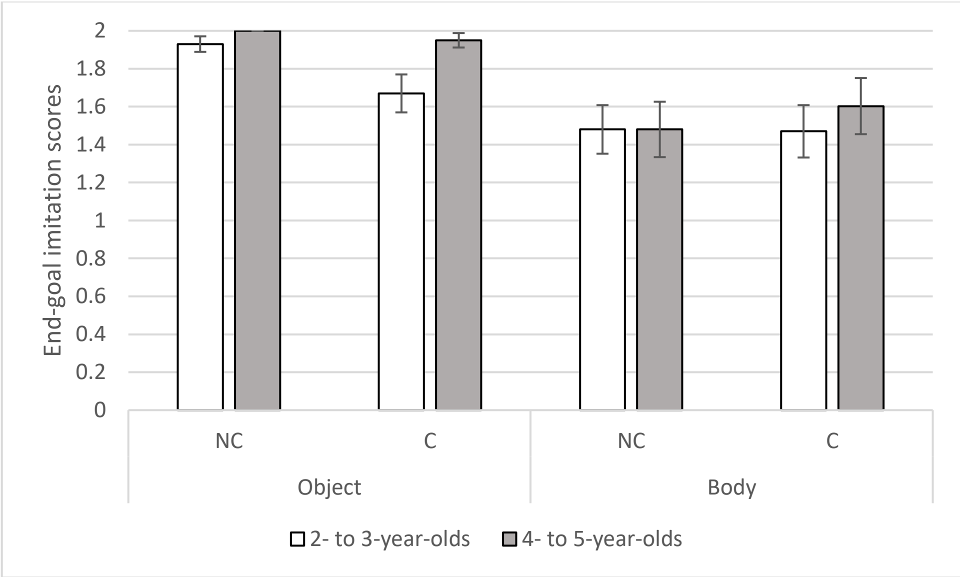


Figure 11B

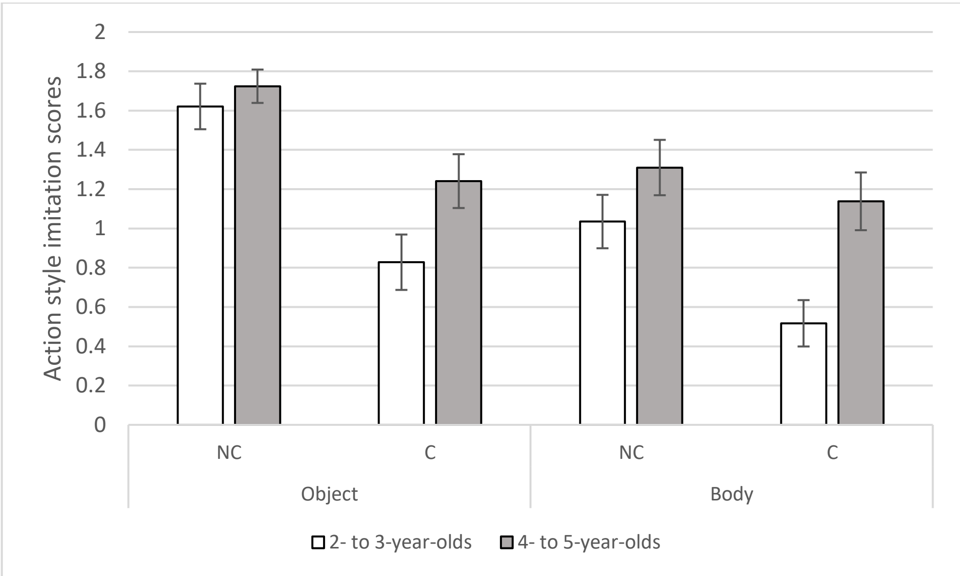


Figure 11. Imitation scores split for context-present (C) and context-absent (NC) condition for both age groups. 11A: End-goal imitation scores. 11B: Movement style imitation scores. Bars indicate standard errors.