The Development of Infants' Action-Related Object Knowledge: Deferred Imitation and Eye Tracking Studies in 12- and 18-Month-Olds

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Contents

Abstract

Imitation paradigms are used in various domains of developmental psychological research to assess various cognitive processes such as memory (deferred imitation), action perception and action understanding (mainly direct imitation), as well as categorization and learning about objects (deferred imitation with a change in target objects and generalized imitation). Although these processes are most likely not independent from each other, their relations are still largely unclear. On the one hand, deferred imitation studies have shown that infants' performance improves with increasing age, resulting in the reproduction of more target actions after longer delay intervals. On the other hand, imitation studies focusing on infants' action understanding have found that infants do not necessarily imitate the model's exact actions – actions or action steps that seem to be irrational or irrelevant are omitted by infants under certain circumstances (selective imitation). Additionally, findings of imitation studies that require a transfer of the target actions to novel objects have demonstrated that infants do not only learn about actions, but also about objects, when they engage in imitation.

The present dissertation aims at integrating different perspectives of imitation research by testing 12- and 18-month-old infants in deferred imitation tests consisting of functional vs. arbitrary target actions, and by combining deferred imitation with eye tracking in half of the experiments. A deferred imitation paradigm was chosen to assess memory performance. Systematic variation of target action characteristics enabled the assessment of infants' imitation pattern, i.e., if they would imitate one kind of target actions more frequently than the other. Functionality was chosen as the action characteristic in focus because function is an object's most important property, thus this variation might shed some light on infants' learning about objects in the context of an imitation test. The main goal of the eye tracking experiments was to tackle the relations between infants' visual attention to, and deferred imitation of, different kinds of target actions.

The behavioral experiments revealed that both 12- and 18-month-olds imitated significantly more functional than arbitrary target actions after a delay of 30 minutes. In addition, while 12-month-olds showed a memory effect only for functional actions, 18-month-olds showed a memory effect for both kinds of actions. Thus, 12-month-olds imitated strictly selectively, and 18-month-olds imitated more exactly. This shows that the well established memory effect is modulated by target action functionality, which affects 12- and 18-month-olds' imitation differently. Furthermore, when retested after a two weeks delay, 18-month-olds' performance rates of functional and arbitrary target actions decreased parallel. This suggests that selective imitation is not affected by the duration of the retention interval, and that selection of target actions takes place at an earlier stage of action perception and memory processes.

In the eye tracking experiments, both 12- and 18-month-olds' imitation patterns replicated the findings of the behavioral experiments, showing consistently higher imitation rates of functional than arbitrary target actions. Contrary to this, infants' fixation times to the target actions were not affected by target action functionality. This contrast was supported by statistical analyses that found no clear correspondence between

visual attention to and deferred imitation of target actions. This suggests that selective imitation cannot be explained by selective visual attention. Nevertheless, finer-grained analyses of gaze and imitation data in the 18 months old group suggested that infants' increased attention to the social-communicative context of the imitation task was related to more exact imitation, i.e. imitation of not only functional, but also arbitrary target actions.

The findings are discussed against the background of imitation theories, with regard to the relations between different cognitive processes underlying infants' imitation, such as memory, action perception and learning about objects.

1
Introduction

1.1. Imitation in Infancy

Imitation is one of the most important learning mechanisms in infancy and early childhood, and an essential tool of cultural transmission (e.g., Gergely & Csibra, 2005; Tomasello, 1999). By observing and copying others' actions, infants learn about cultural products such as objects and their functions, actions typically executed in certain contexts, and language. An early and thorough documentation of imitation in infancy was done by Piaget (1951/1999) who describes how "the child learns to imitate" (p. 5) in the framework of sensorimotor intelligence. According to Piaget, direct imitation is fully developed from about 8 months of age on, when infants are able to imitate movements which they have already performed but which are not visible to them (e.g., tongue protrusion). Trial-and-error imitation is characteristic to this stage, i.e., infants need training in order to reproduce the modeled action. From about 12 months of age on, imitation of new models becomes systematic and exact. Finally, from about 18 months of age on, the previously external experimentation and refinement can be interiorized, and infants do not need any training or trial-and-error imitation. Instead, they become able to immediately imitate new models and also to defer imitation, i.e., to reproduce the model's actions after a delay. Perhaps the most famous instance of deferred imitation was when Piaget's daughter Jacqueline observed a boy's temper tantrum at the age of 1; 4 (3) and imitated this behavior twelve hours later (Piaget, 1951/1999, p. 63, obs. 52). The fact that Jacqueline imitated this previously observed behavior long after the model had disappeared means that "it must have involved some representative or pre-representative element" (p. 63).

More recent studies have shown that Piaget's theory underestimated infants' imitative and representational abilities. For example, direct imitation of facial gestures and other bodily movements has been described in newborns (e.g., Field, Woodson, Greenberg, & Cohen, 1982; Meltzoff & Moore, 1977, 1983) who already show the progressive refinement of actions (Nagy et al., 2005) described by Piaget (1951/1999) in infants aged 8 months and older. Deferred imitation of facial gestures was found in infants as young as 6 weeks (Meltzoff & Moore, 1994), and deferred imitation of object-directed actions was described in 6-month-olds (e.g., Barr, Dowden, & Hayne, 1996) – one year earlier than Piaget (1951/1999) proposed.

Since Piaget's pioneering work imitation paradigms have been applied in different areas of developmental psychology. Details of the imitation paradigm vary depending on the specific research question being addressed, but the core of imitation studies remains the same across various implementations. First, infants observe a model perform one or more object-directed target actions. During this *demonstration phase* infants are not allowed to interact with the target objects. Then, either immediately (immediate or direct imitation) or following a *delay* of some minutes, hours or days (deferred imitation), the target objects are handed to infants in the *recall phase*. To control for spontaneous target action production by infants, either a control group that did not witness the target actions (between-subjects design), or a baseline phase prior to the demonstration phase is applied (within-subjects design). If the amount of target actions performed by infants in the experimental group resp. in the recall phase is significantly higher than the amount of target actions performed by infants in the control group resp. during the baseline phase, this is taken as evidence of (deferred) imitation (Meltzoff, 1985, 1988). The primary difference between direct and deferred imitation paradigms is that while the former relies on short-term memory, the latter requires long-term memory processes (e.g., Abranavel & Gingold, 1985). The most common applications of imitation studies assess infants' and young children's memory and understanding of actions, but imitation can also be used to study categorization processes.

1.1.1. On the concept of imitation

In the previous section, the term imitation has been used rather widely, referring to the reproduction of previously observed actions. However, it has been argued that not all forms of reproducing a previously observed action should be called imitation. In this debate, imitation is most often contrasted with emulation. The main difference between these two forms of learning is that while imitation involves the reproduction of both the observed means (the exact action) and the action goal or end state, emulation means that the learner reproduces the observed action goal or end state by means chosen from his or her own, existing motor repertoire (other than the modeled action). Researchers participating in the emulation/imitation debate disagree on the hierarchy of these two forms of learning, i.e., about the question which one is more insightful and hence developing later, both phylogenetically and epigenetically. Some researchers argue that imitation is a more insightful form of learning, as it involves copying of both actions and action outcomes. Others claim that emulation is more insightful, as understanding the causal relations between objects and effects, thus between the action and the action goal, is a necessary part of emulation, but not of imitation. This disagreement relies, at least partly, on different conceptions of emulation and imitation, and the effort to disentangle the contradicting definitions leads to a finer division of both emulation and imitation (emulation as learning about affordances and causal relations vs. goal emulation, resp. blind imitation vs. insightful imitation). Horner and Whiten (2005) and

Want and Harris (2002) provide detailed reviews of this topic.

Regardless of the hierarchy and the exact definition of emulation and imitation, research has shown that infants from about the age of one year are able to engage in different kinds of social learning, sometimes reproducing both the model's actions and the action goal or end state, and at other times concentrating only on the end state (Gergely, Bekkering, & Király, 2002; Nielsen, 2006). The present dissertation addresses this behavioral dichotomy without aiming to take sides in the imitation/emulation debate for two reasons. First, the question if infants understood the causal relations between objects and target actions was not directly addressed in the experiments, thus no claim can be made about how insightful infants' action reproduction was. Second, the term imitation is used in the present work according to the tradition of deferred imitation studies, i.e., referring to the reproduction of target actions according to operational definitions. This behavior-based definition allows an objective coding of infants' target action performance without presupposing higher cognitive processes (such as understanding the causal relations underlying the target actions) that cannot be assessed by the experimental method of deferred imitation (cf. Paulus, 2011). The term selective imitation will be used to refer to instances in which infants imitate one kind of target action significantly more often than another, and exact imitation will be used to refer to instances when different kinds of target actions are imitated with comparable frequencies.

1.2. Assessing Declarative Memory Performance by Deferred Imitation Tests

Infants' ability for deferred imitation enables long-lasting learning (Hanna & Meltzoff, 1993), and it makes imitation one of the most important ways of acquiring new information in preverbal age. As an experimental paradigm, deferred imitation is the most widely used method to assess infants' long-term declarative memory processes. There are several arguments supporting the claim that deferred imitation assesses declarative memory processes. First, in deferred imitation tests infants acquire novel actions based on a very brief exposure, and they are able to voluntarily reproduce these actions after a delay, without any practice, which rules out motor learning. Even if target objects and actions are not completely novel to infants, comparing the recall of target actions to spontaneous action production in a control group or in a baseline phase controls for prior experience. Second, patients whose declarative memory system is known to be impaired (due to temporal lobe amnesia) are not able to perform deferred imitation. Third, the cross-modal nature of deferred imitation tasks rules out the possibility that imitation might rely on priming processes (Kolling, Goertz, Frahsek, & Knopf, 2009). Furthermore, infants' performance in deferred imitation tests and electrophysiological measures of their long-term declarative memory were found to be related (Carver, Bauer, & Nelson, 2000).

Deferred imitation can be contrasted with elicited imitation (Bauer, 1996, 2005; Bauer & Mandler, 1989), another paradigm used to assess infants' and young children's declarative memory. Elicited imitation is usually applied to study infants' memory for events, i.e., action sequences, by assessing not only the number of action steps remembered, but also the number of action steps reproduced in the right order. The procedure of elicited imitation studies differs from the deferred imitation procedure in three crucial aspects. First, in the demonstration phase both the target objects and the action sequence are verbally labeled by the model. Second, there are two recall phases: one immediately after the demonstration and another following a delay. Third, in the recall phases children are encouraged to imitate the model's actions exactly. Due to the large amount of verbal cues and the possible memory-enhancing effects of the immediate imitation phase, the elicited imitation paradigm is thought to be a less clear method than deferred imitation to assess declarative memory performance (Jones & Herbert, 2006).

Assessment of baseline performance also differs between elicited and deferred imitation studies, although the distinction is not completely clear. Elicited imitation studies routinely apply a within-subjects design, while in deferred imitation studies a between-subjects design is more common. However, in a comparison of within- and between-subjects designs, Kressley and Knopf (2006) showed that both designs are valid and comparable options for assessing baseline performance in deferred imitation studies.

1.2.1. Development of deferred imitation

Infants as young as six months of age are already able to engage in deferred imitation of object-directed actions, although they can only recall a small number of target actions after a delay interval of 24 hours or less (Barr et al., 1996; Collie & Hayne, 1999; Heimann & Nilheim, 2004; Kressley-Mba, Lurg, & Knopf, 2005). With increasing age, infants' deferred imitation performance improves rapidly, as demonstrated by both cross-sectional (e.g., Barr et al., 1996; Meltzoff, 1985) and longitudinal studies (e.g., Kolling, Goertz, Frahsek, & Knopf, 2010; Nielsen & Dissanayake, 2004). After the same retention interval, older infants are able to recall more target actions than younger ones (Barr et al., 1996; Collie & Hayne, 1999; Elsner, Hauf, & Aschersleben, 2007; Kolling et al., 2010). Older infants are also able to retain a significant amount of target actions (i.e., show a memory effect) after longer delays than younger ones (Barr & Hayne, 2000; Carver & Bauer, 2001; Herbert, Gross, & Hayne, 2006; Herbert & Hayne, 2000b). In addition, older infants need fewer repetitions of target action demonstration than younger ones to successfully encode and retain target actions (e.g., Barr et al., 1996). This age-related, quantitative improvement in deferred imitation performance is usually interpreted in the context of developing memory capabilities (e.g., Bauer, 2005; Hayne, 2004; Jones & Herbert, 2006; Knopf, Goertz, & Kolling, 2011).

1.2.2. Factors influencing deferred imitation performance

Besides infants' age, a number of other factors influence infants' deferred imitation performance, such as contextual changes, item-relational information and target action structure. First, the effect of contextual changes interacts with the effect of infants' age.

For example, in a study by Hayne, Boniface, and Barr (2000), 6-month-olds' deferred imitation performance was found to be disrupted by changes in both the testing location and the target object, while 12-month-olds were able to recall the target actions in a new location, but not with a new object. 18-month-olds' performance was affected neither by a location change, nor by a change in the object. A similar improvement of the flexibility of infants' memory was found in 18-, 24-, and 30-month-olds (Herbert & Hayne, 2000a) as well as in 12-, 18-, and 21-month-olds (Hayne, MacDonald, & Barr, 1997).

Second, 10- and 11-month-old (Knopf, Kraus, & Kressley-Mba, 2006), as well as 13-month-old infants (Kressley, Knopf, & Stefanova, 2007) tested in serial deferred imitation studies using multiple items only showed a significant memory effect if the order of the test objects handed to infants in the recall phase was consistent with the order of their appearance in the demonstration phase. Sensitivity for order information was also found in studies applying several target action steps on a single test object, where infants' ability to retain order information increased with age: 25% of 6-month-olds (Barr et al., 1996), 50% of 9-month-olds (Carver, 1999), and 78% of 14-month-olds retained some order information (Bauer, Wenner, Dropik, & Wewerka, 2000).

Third, infants as young as 11 months of age were reported to be sensitive to the causal structure of target action sequences in that they recalled only enabling action sequences and no arbitrary ones after a delay of 24 hours (Mandler & McDonough, 1995). Older infants showed a similar, although weaker effect: both 16- and 20-month-olds were reported to recall enabling action sequences more frequently in the right temporal order than arbitrary ones (Bauer & Mandler, 1992 and Bauer, 1992, respectively). In addition, Elsner and colleagues (2007) found that 9- to 15-month-old infants were more likely to reproduce all three steps of a target action sequence if the last step, instead of the second one, led to a salient effect. Together these findings show that infants do not only encode isolated target action steps, but also the relations between individual action steps, as well as between action steps and their perceivable effects. Although the findings reviewed above suggest that characteristics of the target actions have an effect on infants' performance, action characteristics are rarely taken into account in memory-oriented deferred imitation tests.

1.3. Assessing Action Understanding by Imitation Tests

Target action characteristics play a more essential role in imitation studies designed to assess infants' understanding of observed actions (see Elsner, 2007, for a review) as well as psychological states, such as goals and intentions, of the persons performing these actions (e.g., Bellagamba & Tomasello, 1999; Carpenter, Akhtar, & Tomasello, 1998; Meltzoff, 1995). As infants' interpretation rather than memory of the demonstrated actions is tested in these studies, most of them apply an immediate imitation paradigm. Within this line of research it has repeatedly been shown that infants do not always blindly imitate what they observe. Instead, under certain circumstances they weigh the target actions and imitate some kinds of actions more frequently than others – a phenomenon referred to as selective imitation.

1.3.1. From selective towards exact imitation

Infants around the age of one year imitate in a selective way, i.e., they imitate certain kinds of target actions more frequently than others, based on the actions' perceived intentionality (Carpenter, Akhtar, & Tomasello, 1998), goal-relevance (Brugger, Lariviere, Mumme, & Bushnell, 2007), or efficiency (Gergely et al., 2002; Schwier, van Maanen, Carpenter, & Tomasello, 2006). In contrast, children from about the age of two years have been found to imitate the model's actions exactly, even if omitting some of the action steps would have been beneficial (Nagell, Olguin, & Tomasello, 1993; Nielsen, 2006). This difference between younger infants' selective and older children's exact imitation likely relies on a gradual shift, as 18-month-olds' imitation is neither completely selective, nor completely exact. For example, in a study varying both the model's social-communicative cues and the cognitive transparency of target actions, Nielsen (2006) found that 12-month-olds only copied the model's specific actions if they were given a rational reason to do so, i.e., if the model's choice of action was cognitively transparent to them. Thus, 12-month-olds in this study imitated selectively. 24-month-olds, in contrast, imitated the model's specific actions in all conditions (exact imitation). 18-month-olds imitated selectively when the model acted aloof, i.e., they only imitated the model's actions if the actions seemed to be rational. However, when the model acted socially, 18-month-olds were as likely to copy the specific actions as the actions' outcomes, irrespective of the apparent rationality of the actions. The same trend was found by Tennie, Call and Tomasello (2006) in a study with 12-, 18-, and 24-months-olds and by Carpenter, Call and Tomasello (2005) in a study with 12- and 18-month-olds.

1.3.2. The role of the social-communicative context of imitation

Piaget's (1951/1999) theory postulates that imitation is a way of dealing with the puzzlement created by the model's action when the infant's assimilatory schemes are insufficient to do so, thus it is a cognitive view. Contrary to this, the interpersonal view defines imitation as a way of realizing the possible congruence between two individuals, which originates in affective sharing (Uzgiris, 1981). According to Uzgiris, these two views represent two sides of the same coin: imitation serves both a cognitive and a social function. In younger infants, around the age of 10 months, the cognitive function dominates. From the age of 16 months on, however, social motivations become more important and infants start to use imitation to maintain the social interaction with the model. Consequently, infants' imitation in a specific situation may be influenced by the interaction of cognitive and social motivations (Over & Carpenter, 2012; Uzgiris, 1981). The cognitive function of imitation has been extensively investigated by deferred imitation tests, and its everyday relevance is reflected by the observation that infants acquire 1-2 new behaviors every day by observing and imitating other people (Barr & Hayne, 2003). The social-communicative function of imitation is also confirmed by observations in both laboratory and everyday settings showing that infants from the age of 18 months on communicate with their peers by imitating each other. These social exchanges are characterized by turn-taking and role-switching, suggesting that they do not serve teaching and learning, but communication (Nadel, 2002).

Furthermore, empirical evidence supports the importance of the social-communicative context between the model and the infant in imitation tests. Studies varying the model's social availability showed that infants imitate more exactly if the model is present and socially available than when the model is absent or socially less available (Király, 2009; Nielsen, 2006; Nielsen, Simcock, & Jenkins, 2008). Infants' sensitivity and attention to the model's social-communicative cues, on the other hand, have not been investigated. Theoretically, however, it has been described that not only the model's social-communicative cues, but also the infant's sensitivity to these cues are necessary to establish a social-communicative context that can lead to exact imitation ("pedagogical context", see Csibra & Gergely, 2006; Gergely & Csibra, 2005). It is reasonable to assume that not only the model's social availability, but also different levels of infants' engagement in the social-communicative context can lead to differences in imitative behavior within the same age group. 18-month-olds, who as a group imitate more exactly than 12-month-olds but more selectively than 24-month-olds (Nielsen, 2006), are particularly interesting from this point of view, as the imitation pattern observed on a group level might result from individual differences, i.e., some infants imitating selectively and others imitating more exactly.

1.3.3. The role of the target actions

Besides infants' age and the social-communicative context, target action characteristics also have an effect on what infants imitate (cf. Section 1.2.2). For example, infants are more likely to imitate target actions that seem to be performed intentionally than target actions that seem to be performed accidentally (Carpenter, Akhtar, & Tomasello, 1998). Additionally, infants are more likely to imitate a target action if it leads to a salient effect (Elsner et al., 2007). Both intentionality and action effects are factors that usually coincide with functional object use, which suggests that a more general action property, namely, functionality, might lie in the background of these effects. There are a few studies discussing that infants do not only acquire actions, but also learn something about object functions via imitation (e.g., Elsner & Pauen, 2007). Furthermore, infants are able to generalize the information acquired by imitation to novel, but similar objects (Barnat, Klein, & Meltzoff, 1996; Bauer & Dow, 1994; Hayne et al., 1997; Herbert & Hayne, 2000a). Despite this evidence, however, systematic effects of target action functionality have never been described in imitation studies.

Understanding the effects of target action functionality on infants' imitation would be important for at least two reasons. First, assessing the effects of functionality instead of the effects of individual factors related to functionality would more directly tackle the question if young infants' imitation is really driven by a motivation to learn about object functions (Uzgiris, 1981). Second, as learning about object functions and establishing representations of function-based object categories requires long-term declarative memory processes, the effects of target action functionality are also centrally relevant for deferred imitation as a memory test.

1.3.4. Theories on the background of selective imitation

Several theoretical accounts have been proposed to explain selective imitation. Some of these claim that selective imitation can be explained by lower level, automatic processes, while others argue for higher cognitive, interpretative processes as a background of (selective) imitation. One of the lower-level accounts conceptualizes imitation as direct mapping of the observed actions onto one's own motor repertoire, combined with action-effect binding (Hauf & Prinz, 2005; Meltzoff, 2007; Paulus, Hunnius, Vissers, & Bekkering, 2011a). In this line of research, a two-stage model of infants' imitative learning was proposed (Paulus, Hunnius, Vissers, & Bekkering, 2011b). First, observing another person's action activates the corresponding motor code in the infant's motor repertoire (motor resonance). If the observed action was followed by a salient effect, the representation of the effect will be associated with the activated motor code (action-effect binding). Then, if the infant intends to bring about the same effect, the corresponding motor program will be activated through the action-effect association. This theory can explain some important issues related to selective imitation–e.g., why actions with salient effects are imitated more frequently than actions without salient effects (Elsner, 2007)–, but it does not provide an explanation for the developmental shift from selective towards exact imitation, nor for the dependency of imitation on situational constraints such as the model's social-communicative cues.

Higher-level theories, proposing that imitation involves some interpretation of the modeled actions, explain the developmental shift from selective towards exact imitation by changes in the nature of action interpretations. For example, Gergely (2003) describes a shift from teleological to mentalizing action interpretation. This means that 14-month-olds interpret the observed actions in terms of their visible outcomes and situational constraints (teleological interpretation), and they only copy the model's actions if those seem to be efficient (Gergely et al., 2002). Contrary to this, 18-month-olds attribute a communicative, teaching intention to the model (mentalizing interpretation), and thus they exactly imitate the model's actions irrespective of the apparent efficiency of the actions (Gergely & Király, 2003, as cited by Gergely, 2003; cf. Nielsen, 2006). This theory is consistent with the change from object-centered to social imitation as described by Uzgiris (1981).

1.4. Relations Between Memory Processes and Selective Imitation

The studies and theoretical accounts described above show that throughout the second year of life, infants' imitation changes both quantitatively (see Section 1.2.1) and qualitatively (see Section 1.3.1). While the quantitative improvement has been explained by advancing information processing and memory capabilities (Barr et al., 1996; Elsner et al., 2007; Kolling et al., 2010), the qualitative change is attributed to changes in infants' motivational background and sensitivity to social-communicative cues (Gergely, 2003; Uzgiris, 1981). Most likely, these changes are not independent from each other. On the one hand, it is possible that target actions that are usually omitted in young infants' selective imitation, such as actions without effects, are more difficult to encode and recall than other actions. Older children's more advanced information processing and memory capabilities could result in the recall of also these, more difficult target actions. On the other hand, it is also possible that the quantitative improvement in infants' imitation can be explained by a change in infants' action interpretation. Mentalizing, as opposed to teleological, action interpretation leads to more exact imitation, which means successful recall of different kinds–and thus a larger number–of target actions. These processes, i.e. the relations between memory capabilities and selective imitation are, however, still unclear.

1.5. Assessing Categorization by Imitation Tests

As described in Section 1.2.2, infants are able to generalize the target actions of a deferred imitation test to objects that are similar to, but not identical with the demonstration objects. At a first glance, generalization to novel objects might seem as a result of forgetting the original test objects' features. However, there are some arguments against this assumption, as summarized by Jones and Herbert (2009). First, younger infants forget faster than older ones, so if generalization was due to forgetting, younger infants would generalize more readily than older ones. However, the opposite is the case. Second, longer delays affect more information than shorter ones. Thus, if generalization resulted from forgetting, infants would generalize more target actions after longer delay intervals than after shorter ones. Again, the opposite is true. Third, both verbal labels accompanying target action demonstration and physical experience with the test objects facilitate generalization. This is consistent with findings showing that both object names and object functions are important cues to categories for infants. This suggests that infants generalize a target action to a new object because they recognize the similarities between the objects and infer that the new object is also suitable to perform the target action with. Although generalization in deferred imitation studies is usually interpreted in terms of representational flexibility (e.g., Herbert & Hayne, 2000a), it also indicates that infants are able to form function-based categories that entail both the demonstration object and the test object.

A different paradigm, namely generalized imitation, is often used to assess categorization processes in infants aged 9 to 14 months (Mareschal & Quinn, 2001). In these tasks infants observe an experimenter perform a target action using a demonstration object and a prop. The target action is usually accompanied by a vocalization. For example, the experimenter takes a toy dog (demonstration object), puts it in a toy bed (prop) and says "night-night". Immediately after this demonstration phase the experimenter places two test objects, namely a target (a new object from the same category as the demonstration object) and a distractor (a new object from a different category) on the table in front of the infant. Then the experimenter hands the prop to the infant, and repeats the vocalization as a prompt for imitation (recall phase). The infant's object choice for imitation of the target action is interpreted as an indicator of which of the two objects he or she considers to belong to the same category as the demonstration object. To control for spontaneous target action production, infants' baseline performance is assessed prior to the demonstration phase (Mandler & McDonough, 1996; Mareschal & Quinn, 2001). Generalized imitation studies strengthen the argument that infants' imitation does not only reflect their action acquisition, but also their developing object knowledge and categorization.

1.6. The Role of Functions in Learning About Everyday Objects

Function is the most important information children have to learn about objects in order to navigate in the world. Object function is also a central concept in research on the development of object knowledge. According to one of the most influential theories on the development of object concepts, the intended function of an object is its essence, i.e., the reason for its existence that constrains both its physical properties and the possible actions that can be performed on it (Kelemen & Carey, 2007). Although infants do not understand the causal relations between an object's intended function and its properties or possible uses in their full depth (e.g., design history starts to influence object categorization at preschool age, see Gelman & Bloom, 2000; Matan & Carey, 2001), function-related object properties already play an important role in infants' learning about objects and actions.

In the second half of the first year infants' developing abilities to communicate with other people, as well as to alternate their gaze between an object and another person, enable infants to participate in joint object-centered engagements with their caregivers. During these engagements, caregivers often attempt to increase infants' exploration and understanding of the objects focused on, by pointing out relevant object properties or possible actions the infant could carry out on them (Williams, 2003). From the end of the first year of life, infants show sensitivity to several factors related to object functionality. First, from 12 months of age, salient action effects influence infants' imitation in that infants imitate actions that lead to salient effects more readily than effectless actions (Elsner, 2007). Second, infants are able to interpret actions as goal-directed and to infer which of the possible actions would be the most efficient one to reach a certain goal in the given circumstances (Gergely & Csibra, 2003). Third, 14- to 18-month-old infants are able to distinguish intentional from accidental actions if these are vocally labeled as such, and they imitate the intentional actions more frequently than the accidental ones (Carpenter, Akhtar, & Tomasello, 1998). Fourth, the emergence of functional play shows that by the beginning of their second year of life, infants have acquired some conventional ways of handling everyday objects (Casby, 2003). Then, by the age of two years, toddlers adopt the view that certain objects and functions belong together. When they encounter an object in a social-communicative context, such as an imitation task, they regard the object as being *for* the presented function and avoid using it for a different one (Casler & Kelemen, 2005).

2

The Present Research Project

2.1. Overview of Dissertation-Relevant Manuscripts

Paper 1

Óturai, G., Kolling, T., Rubio Hall, L., & Knopf, M. (2012). The role of object functions for deferred imitation – Do infants selectively retain and forget target actions? *Infant Behavior and Development, 35*, 195-204.

Paper 2

Kolling, T., Óturai, G., & Knopf, M. (in press). Is selective attention the basis for selective imitation in infants? An eye-tracking study of deferred imitation with 12 month-olds. *Journal of Experimental Child Psychology.*

Paper 3

Óturai, G., Kolling, T., & Knopf, M. (2013). Relations between 18-month-olds' gaze pattern and target action performance: A deferred imitation study with eye tracking. *Infant Behavior and Development, 36*, 736-748.

2.2. Motivation and Goals of the Experiments

> "A major goal of research on the development of observational learning and imitation is to use patterns of success and failure on different types of tasks to infer the probable processing achievements that are being mastered with growth. We need to know more precisely what it is that children at each age acquire from modeling and how well they retain that information."
>
> Abranavel & Gingold, 1985, p. 621

As described in the Introduction, infants' imitation undergoes significant development in the first half of the second year, both quantitatively (see Section 1.2.1) and qualitatively (see Section 1.3.1). The initial motivation of the present dissertation project was to tackle the relations between quantitative and qualitative change in infants' imitation by bringing two branches of imitation research, i.e., memory-oriented deferred imitation research and research on selective imitation, closer together. Although developmental change cannot be directly assessed by cross-sectional designs, testing 12- and 18-month-old infants with similar versions of the same experiment might offer some insight into the relations of selective imitation and memory processes at these two stages of development.

As learning about objects and how they work is one of the most important functions of imitation (Uzgiris, 1981), the present experiments focused on how infants acquire actions of varying functionality through imitation. While previous studies varied individual function-related factors such as intentionality or action effects, in the present dissertation a more global view on functionality was applied. This view was in accordance with the position that the concept of function does not consist of a single trait of an object, but rather a complex set of function-related knowledge, including physical properties, the settings in which the object can usually be found, and the actions that can be performed with the object (Chaigneau, Barsalou, & Sloman, 2004). Consequently, the effects of target action functionality on infants' imitation cannot be assessed by the variation of a single function-related action characteristic. Some functional actions in the present experiments resulted in a salient sound effect, others led to a visible end state, and some others presented the object's conventional function. The common factor in functional actions is that they always require specific object properties, while arbitrary actions can be performed on a wide array of objects. For example, the functional action demonstrated on one of the objects used in all experiments, a wooden mouse, is to press the mouse, thus shutting it, which leads to a clicking noise. This action is enabled by the material and specific structure of the mouse and it could not be performed, for example, on a soap bar, even though the overall shape of the two objects is similar. Contrary to this, the arbitrary action demonstrated on the mouse, namely sliding it across the table, could be performed on a wide range of objects, such as soap bars, cell phones, coffee mugs, toy cars, dolls and so on.

Investigating infants' imitation of functional vs. arbitrary target actions in a deferred imitation paradigm can be beneficial for at least two reasons. First, systematic variation of target action functionality in deferred imitation tests can lead to important test-theoretic insights, as target actions differing in functionality might also differ in their difficulty. Additionally, it enables the comparison of both quantity (imitation rates) and quality (selective imitation) of 12- and 18-month-old infants' imitative learning. Second, assessing selective imitation in a deferred imitation test, as opposed to immediate imitation, can enable the investigation of all stages of learning different kinds of actions, from observation and encoding to long-term retention and reproduction of target actions (Abranavel & Gingold, 1985).

To this end, a series of deferred imitation experiments applying both functional and arbitrary target actions was designed to investigate 12- and 18-month-olds' deferred imitation of these actions. Additionally, the question what processes might account for selective imitation arose. Existing theories on this question propose either that selective imitation can be explained by lower-level processes, such as motor resonance (e.g., Paulus et al., 2011a, 2011b), or that higher cognitive processes, such as teleological action interpretation (e.g., Király, Csibra, & Gergely, 2013) account for the selection of target actions. Although implicitly, both of these theories presume that infants attend to all kinds of target actions equally, infants' visual attention towards different kinds of target actions and their imitation of the same actions had not been investigated before.

2.3. Hypotheses

First of all, since the main goal of the experiments was to bring together memory-oriented deferred imitation research and research on selective imitation processes, replicating former important findings of both of these areas was a necessary prerequisite of further analyses carried out in the present work. Thus, it was expected that both 12- and 18-month-old infants would engage in deferred imitation, i.e., show a memory effect in all experiments (Papers 1, 2, and 3). Infants were also expected to imitate significantly less target actions after a two-weeks-delay than after a 30-min-delay, indicating forgetting (Paper 1). Additionally, both 12- and 18-month-olds were expected to imitate significantly more functional than arbitrary target actions in all experiments, demonstrating selective imitation in deferred imitation tasks (Papers 1, 2, and 3). Furthermore, it was expected that 12-month-olds would imitate entirely selectively, i.e., show a memory effect only for functional target actions, whereas 18-month-olds would imitate more exactly, i.e., show a memory effect for both functional and arbitrary target actions – replicating the previously described developmental trend from selective towards more exact imitation (Papers 1, 2, and 3).

The combination of a deferred imitation setting and a test material designed to assess selective imitation (systematic variation of functional vs. arbitrary target actions) enabled the analysis of long-term retention and forgetting of different kinds of target actions, which had not been addressed by previous studies. In this respect it was expected that arbitrary target actions that do not express relevant information about the objects would be forgotten faster than functional ones, indicating selective forgetting (Paper 1).

By assessing infants' gaze towards the videotaped target actions during the demonstration phase in half of the experiments, the hypothesis that selective visual attention might account for selective imitation was tested (Papers 2 and 3). As in the eye tracking experiments target actions were presented to infants via video, according to the video deficit effect (Barr, 2010), deferred imitation performance rates were expected to be lower than following a live demonstration (Papers 2 and 3).

2.4. Method

2.4.1. Experiments and Participants

The present dissertation project consists of four experiments which are summarized in Table 1.

Table 1.
Overview of experiments.

Experiment	Paradigm	Age group	Sample size	Publication
Experiment 1	Classical deferred imitation	12 months	N=31	Paper 1
Experiment 2		18 months	N=31	
Experiment 3	Deferred imitation with video demonstration and eye tracking	12 months	N=23	Paper 2
Experiment 4		18 months	N=20	Paper 3

Experiments 1 and 2 were classical, behavioral deferred imitation experiments with 12- resp. 18-month-old infants (Paper 1). In Experiments 3 and 4, the deferred imitation paradigm was combined with eye tracking during the demonstration phase, hence the target actions were presented to 12- resp. 18-month-old infants via video (Papers 2 and 3). Participants were recruited using a database of potentially interested families and their children, and by word of mouth. All caregivers gave their written informed consent before the procedure of the experiments started. The final total sample of the experiments included N = 54 twelve-month-olds (31 girls, age range: 353-379 days, M = 368.6 days, SD = 7.3) and N = 51 eighteen-month-olds (26 girls, age range: 537-564 days, M = 552.3 days, SD = 7.5). Detailed information about participants, as well as about infants who were tested but not included in the final sample can be found in the Method sections of the respective manuscripts.

2.4.2. Material and Apparatus

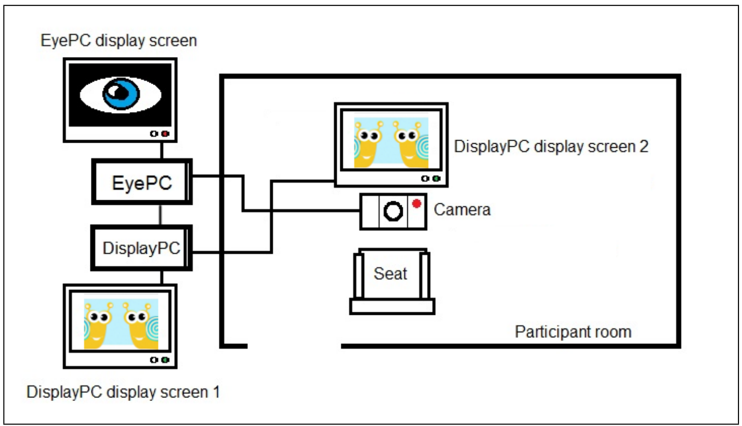
Deferred imitation tests

The objects and target actions used in all four experiments were adapted from deferred imitation tests that had been previously developed and standardized at the Developmental Psychology Lab of the Goethe-University Frankfurt. In Experiments 1 and 3 an adapted version of the Frankfurt Imitation Test for 12 Months Old Children (FIT 12, Goertz, Knopf, Kolling, Frahsek, & Kressley, 2006), and in Experiments 2 and 4 an adapted version of the Frankfurt Imitation Test for 18 Months Old Children was used (FIT 18, Goertz, Kolling, Frahsek, & Knopf, 2008). Both the FIT 12 and the FIT 18 consist of several (5 resp. 6), age-appropriate items. Each item consists of one or two objects (e.g., a bowl and a stirrer). The target actions of both the FIT 12 and the FIT 18 were changed in a way that with each item a functional and an arbitrary target action could be demonstrated. The objects and target actions of the adapted FIT 12 resp. FIT 18 are shown in Tables 2 resp. 3. Functional and arbitrary target actions in the present experiments were independent from each other, which means that they were not constrained by an overall action goal, and they could be performed in both orders.

Eye-tracking system

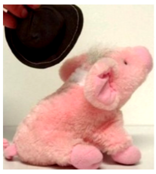
In Experiments 3 and 4, infants' eye movements were recorded while they were watching the target action demonstration video. To this end, an Eye Link 1000® (SR Research Ltd.) was used. The infrared eye-tracking camera was fixed beneath the presentation screen, and the experimenter controlled stimuli presentation and eye movement recording via two personal computers in an adjacent room. An overview of the eye tracking room is presented in Figure 1. Details on the eye tracker's technical specifications can be found in the Method sections of the respective manuscripts (Papers 2 and 3).

Figure 1.
Schematic view of the eye-tracking room



Note. Image by Sebastian Betz. Reprinted with permission.

Table 2.
The adapted FIT 12, used in Experiments 1 and 3 with 12-month-olds.

Item	Objects	Target action 1 and operational definition	Target action 2 and operational definition
Tin can		Blowing on the tin *Will be coded as yes, if the child blows or tries to blow on the tin*	**Shaking the tin up and down (sound effect)** *Will be coded as yes, if the child shakes the tin at least twice up and down or in any other direction*
Pig and hat		**Placing the hat on the pig's head** *Will be coded as yes, if the child places the hat somewhere on the pig*	Lifting the pig and placing it back on the table ("jumping") *Will be coded as yes, if the child lifts the pig and places it back on the table, regardless if the hat is on the pig*
Bowl and stirrer		Placing the bowl on the other side of the stirrer *Will be coded as yes, if the child lifts the bowl and places it on the other side of the stirrer or lifts the stirrer and places it on the other side of the bowl*	**Turning the bowl and stirring in it** *Will be coded as yes, if the child turns the bowl around and puts one end of the stirrer in it*
Mouse		**Shutting the mouse four times (sound effect)** *Will be coded as yes, if the child shuts the mouse, even if it is too weak to produce a sound*	Sliding the mouse on a curvy path *Will be coded as yes, if the child pushes the mouse forward on the table*
Drum		Sliding the drumstick around the drum *Will be coded as yes, if the child slides the drumstick around or next to the drum*	**Pressing the red button (sound effect)** *Will be coded as yes, if the child presses the red button on the drum*

*Note.*Functional target actions are printed in bold, arbitrary target actions in regular font, and operational definitions in italics.

Table 3.
The adapted FIT 18, used in Experiments 2 and 4 with 18-month-olds.

Item	Objects	Target action 1	Target action 2
Ship		Taking the ship from one hand to the other and back *Will be coded as yes, if the child takes the ship from one hand to the other*	**Putting a hand into the ship and waving** *Will be coded as yes, if the child puts a hand into the ship*
Cow and metal box		**Clicking the box on the cow's belly** *Will be coded as yes, if the child clicks the box on the cow's belly, even if the magnets do not hold*	Lifting the cow and placing it back on the table ("jumping") *Will be coded as yes, if the child lifts the cow and places it back on the table, regardless if the box is on the cow's belly*
Mouse		**Shutting the mouse four times (sound effect)** *Will be coded as yes, if the child shuts the mouse, even if it is too weak to produce a sound*	Sliding the mouse on a curvy path *Will be coded as yes, if the child pushes the mouse forward on the table*
Frog and ring		Sitting the frog in the ring and sliding it to and fro *Will be coded as yes, if the child slides the frog to and fro on the table, regardless if the frog is sitting in the ring*	**Putting a finger into the frog and holding it upright** *Will be coded as yes, if the child puts a finger in the frog*
Drum		Sliding the drumstick around the drum *Will be coded as yes, if the child slides the drumstick around or next to the drum*	**Pressing the red button (sound effect)** *Will be coded as yes, if the child presses the red button on the drum*
Duck and octopus		**Sitting the duck on the octopus** *Will be coded as yes, if the child places the duck on the octopus*	Turning the duck *Will be coded as yes, if the child turns the duck, regardless if the duck is sitting on the octopus*

*Note.*Functional target actions are printed in bold, arbitrary target actions in regular font, and operational definitions in italics.

2.4.3. Procedure

An overview of the procedures of each experiment is presented in Table 4.

Table 4.
Procedure of the experiments

Experiment 1	Experiment 2	Experiment 3	Experiment 4
Baseline			
Live demonstration of target actions		Video demonstration of target actions and eye tracking	
30 minutes delay			
Recall phase			
	2 weeks delay		
	2^{nd} recall phase		

All four experiments followed the basic procedure of within-subjects design deferred imitation tests, consisting of a baseline phase in which infants' spontaneous target action production is assessed, a demonstration phase in which the model performs the target actions, a delay interval, and a recall phase in which infants' deferred imitation performance is assessed. The baseline phase of each experiment took place in the same, sparsely furnished laboratory room. The infant was seated on the caregiver's lap at a table, opposite to the experimenter. Caregivers were asked to refrain from interacting with their infants, and especially from giving hints about the functions and names of the objects. After approximately two minutes of warm-up play with an attractive toy, baseline testing began. The experimenter took the first object from a hidden container and placed it on the table in front of the infant. The experimenter directed the infant's attention to the object by saying: "Look, [Name]! You can play with this." If necessary, the experimenter repeated the encouragement to play with the object. After 30 seconds the experimenter removed the object and placed the next one on the table, saying: "Look, [Name], now you can play with this one." The same procedure was repeated for all target objects. The infant's playing behavior was videotaped by two cameras.

Infants in Experiments 1 and 2 witnessed a live target action demonstration which took place immediately after the baseline phase, at the same table in the laboratory room. In Experiment 1, the experimenter demonstrated each pair of target actions four times. In Experiment 2, each pair of target actions was demonstrated three times[1]. The experimenter actively communicated the demonstration of new information, saying "Look, [Name], I will show you something!... Look, I will show it again." In Experiments

[1]Frequencies of target action demonstration relied on the age-adapted deferred imitation tests FIT 12 (Goertz et al., 2006) and FIT 18 (Goertz et al., 2008).

3 and 4, target actions were demonstrated via video, and infants' eye movements were assessed during target action observation. In these experiments, infants and caregivers were escorted to the eye-tracking room immediately after the baseline phase. Here, infants were seated on their caregiver's lap in front of the eye tracker screen. The experimenter performed a short setup, as well as calibration and validation routine, and then the action demonstration video was presented and infants' eye movements were recorded. The action demonstration video showed the experimenter sitting at a table and performing the target actions in the same way as in a live demonstration.

There was a 30 minutes long delay in all experiments. During this delay infants and caregivers stayed in the waiting room. The infant participated in no additional tasks and was free to play. In Experiment 2 an additional delay of two weeks was applied in order to assess long-term retention and forgetting.

Deferred imitation recall phase took place in the same laboratory room as baseline testing in all experiments, and it followed the same procedure. The experimenter placed the objects subsequently on the table in front of the infant and encouraged the infant to play with them, saying "Look, [Name]! You can play with this". Infants' playing behavior was videotaped again by two cameras.

2.4.4. Data Analysis

Deferred imitation data

In each experiment, infants' videotaped performance of target actions in the baseline and the recall phase was scored by a naive rater according to the operational definitions given in Tables 2 and 3. One third of the videotapes were additionally scored by a second rater. Both raters were blind to the hypotheses of the experiments. Inter-rater reliability was high throughout the experiments ($\kappa_{min} = .81, \kappa_{max} = .90$, all ps $< .001$), and rater disagreement was resolved by forced consent.

Traditionally, target action performance rate in the baseline phase is compared to target action performance rate in the recall phase in order to test a memory effect. This analysis was conducted in all experiments. In addition, a new analysis of imitation performance was introduced in Experiments 3 and 4. In this analysis the number of newly acquired target actions was computed and compared to zero. Newly acquired target actions are those that an infant performed in the recall phase, but had not already performed in the baseline phase, making it likely that he or she acquired it during the demonstration phase. This can be considered a more conservative measure of deferred imitation. In addition, based on the imitation frequencies of individual target actions, item difficulty can be computed. This was also done in all experiments, although not always reported in the respective manuscripts. Analysis of item difficulties can be useful, for example, to assess whether selective imitation according to target action functionality was consistent across items.

Eye tracking data

The rationale of the eye tracking measurement and analysis in the present deferred imitation experiments was to assess which parts of the screen infants looked at during relevant parts of target action demonstration, namely when the model was talking and when she or he[2] was performing the target actions. Thus, the analysis of eye tracking data focused on infants' gaze pattern (fixations and saccades) during the aforementioned relevant periods (Periods of Interest, POIs), within the screen areas displaying important stimuli (Areas of Interest, AOIs).

Two kinds of POIs were defined: Talking POIs and Target Action POIs. During Talking POIs the video showed the model with one of the test objects in front of her or him on the table, talking to the infant and establishing a social-communicative context by saying "Look! I will show you something", before the first demonstration of an item, or "Look! I will show it again", before every consecutive demonstration. During Target Action POIs the video showed the model demonstrating the functional and arbitrary target actions (Functional Target Action POIs and Arbitrary Target Action POIs). Talking POIs were defined for each demonstration of each item (5 items $\times$ 4 demonstrations in Experiment 3 and 6 items $\times$ 3 demonstrations in Experiment 4), and Target Action POIs were defined for each demonstration of each target action (5 items $\times$ 4 demonstrations $\times$ 2 target actions in Experiment 3 and 6 items $\times$ 3 demonstrations $\times$ 2 target actions in Experiment 4).

For each POI, two kinds of AOIs were defined: a Face AOI and an Action AOI. The Face AOI contained the model's face during both Talking POIs and Target Action POIs. The Action AOI contained the object in front of the model during Talking POIs and both the object and the model's acting hand during Target Action POIs. All AOIs were rectangular, defined by pixel coordinates of the extreme positions of the AOIs' content during a certain POI.

Fixation times were taken as the main measure of infants' visual attention towards specific areas of the demonstration video during different scenes, thus fixation times to the Face AOI resp. the Action AOI during Talking POIs, Functional Target Action POIs and Arbitrary Target Action POIs were analyzed. Additionally, the amount of fixations was also analyzed with respect to the different AOIs and POIs. To compensate for differences in POI duration and AOI size, all fixation times and amounts of fixations were corrected. To account for differences in POI duration, both the amounts of fixations and fixation times were computed as the percentage of total POI length. Additionally, to account for differences in AOI sizes, these percentage values of fixation times and amounts of fixations were divided by the relative size of the corresponding AOI (size of AOI divided by screen size). Additional analyses were conducted on the amount of saccades between the Face AOI and the Action AOI during different POIs (Experiments 3 and 4), as well as on the amount of saccades within both of the AOIs (Experiment 3). To compensate for differences in POI duration, all amounts of saccades were computed as the percentage of total POI length.

[2]Experiment 3 was conducted by a female experimenter and Experiment 4 by a male experimenter.

2.5. Results and Discussion

2.5.1. Selective Deferred Imitation

In Experiments 1 and 2 twelve- respectively eighteen-month-old infants were tested with deferred imitation tests consisting of functional and arbitrary target actions. After a delay interval of 30 minutes, 12-month-olds performed significantly more target actions than in the baseline phase, showing a memory effect. 18-month-olds, who were tested both after 30 minutes and after two weeks, showed a memory effect after both delay intervals. When retested after a delay of two weeks, 18-month-olds performed significantly less target actions than after the 30 minutes delay, indicating forgetting (cf. Bauer et al., 2000; Klein & Meltzoff, 1999). These results replicate a series of former findings showing that 12- and 18-month-old infants are able to recall several target actions after a delay (e.g., Barr et al., 1996; Kolling et al., 2009). In addition, the results confirm that the adapted versions of the FIT 12 (Goertz et al., 2006) and the FIT 18 (Goertz et al., 2008) are suitable for assessing declarative memory.

Not all target actions were, however, imitated equally frequently. In fact, both 12- and 18-month-olds imitated significantly more functional than arbitrary target actions, thereby engaging in selective imitation. Selective imitation was consistent across items in both age groups, i.e., in each item the functional action was imitated more frequently than the arbitrary one, showing that different kinds of functional target actions were dealt with by infants in a similar way. Furthermore, imitation performance of the two age groups differed in that while 12-month-olds imitated almost exclusively functional target actions (i.e., they showed no memory effect for the arbitrary ones), 18-month-olds imitated both kinds of actions, but still more functional than arbitrary ones after the 30 minutes delay. This difference between age groups replicates former findings (Nielsen, 2006; Tennie et al., 2006), and it is in line with the idea that although social motivations become important around the age of 18 months, infants are still motivated to learn about object functions (Uzgiris, 1981). When retested after two weeks, 18-month-olds' memory performance for functional and arbitrary target actions decreased parallel. This suggests that selective forgetting does not play a role in selective deferred imitation, i.e., the selection of target actions to be imitated takes place at an early stage of the action observation and memory processes.

2.5.2. Selective Deferred Imitation of Videotaped Target Actions

For the purposes of Experiments 3 and 4, the demonstration of target actions was videotaped and implemented in eye tracking experiments that allowed the recording of infants' eye movements while they were watching the action demonstration videos. Infants in both experiments showed a memory effect, although imitation rates were lower than in Experiments 1 and 2. Thus, infants were able to acquire some new actions from the video demonstrations, despite the video deficit effect (Barr, 2010). Additionally, both selective deferred imitation and the age difference found in Experiments 1 and 2 were replicated.

2.5.3. Infants' Eye Movements During Target Action Observation

The main question of Experiments 3 and 4 was whether infants attend more to functional than to arbitrary target actions, as a background of their preferential imitation of functional actions as found in Experiments 1 and 2. To tackle this question, infants' fixation times to the Action AOI during Functional vs. Arbitrary Target Action POIs were compared. Results showed that 12-month-olds' fixation times to the Action AOI did not differ between Functional and Arbitrary Target Action POIs. 18-month-olds' overall fixation times to the Action AOI were, however, longer during Arbitrary than during Functional Target Action POIs. Nevertheless, this difference was not consistent across items, as fixation times to the Action AOI were longer during Arbitrary Target Action POIs than during Functional ones in some items, while in other items the opposite was true. Thus, fixation times to the Action AOI did not vary according to target action functionality in either of the two age groups. Additionally, infants' fixation times to the Face AOI did not differ depending on target action functionality, either. This shows that target action functionality, which affected infants' deferred imitation performance, did not systematically affect their fixation times towards the demonstration screen.

Further analyses revealed that infants in both age groups had longer fixation times to the Action AOI than to the Face AOI during Target Action POIs. 12-month-olds also looked longer to the Action AOI than to the Face AOI during Talking POIs (note that in these POIs the Action AOI contained a stationary object in front of the model). This difference was not found in 18-month-olds who looked to the model's face as long as to the object while the model was talking. In addition, analyses of the amount of saccades between the Face AOI and the Action AOI during different POIs revealed some interesting differences between age groups. 18-month-olds' amount of saccades between the Face AOI and the Action AOI was larger during Talking POIs than during both Arbitrary and Functional Target Action POIs, and it was larger during Arbitrary Target Action POIs than during Functional Target Action POIs. The increased amount of saccades between the model's face and the target action during Arbitrary Target Action POIs might be an indicator of infants looking for an explanation for the arbitrary actions in the model's face (cf. Vivanti, Nadig, Ozonoff, & Rogers, 2008). The even higher amount of saccades during Talking POIs suggests that infants were engaging in a joint-attention-like episode with the model while he was talking and establishing a social-communicative context between himself, the object and the infant. Neither of these differences was found in 12-month-olds, which supports the interpretation that the increased number of saccades between the Face AOI and the Action AOI during Arbitrary Target Action POIs and Talking POIs reflect infants' social-cognitive abilities that undergo significant development over the first two years of life (Corkum & Moore, 1998; Morales et al., 2000, but see Carpenter, Nagell, & Tomasello, 1998 for a different view).

2.5.4. Relations Between Infants' Gaze Behavior and Deferred Imitation

Eye tracking and deferred imitation data of both age groups demonstrated that even though functional target actions were imitated more frequently than arbitrary ones throughout all items in both experiments, infants' eye movements during the observation of target actions did not show the same pattern, i.e., infants did not spend consistently longer fixation times on functional than on arbitrary target actions.

Additional analyses provided more direct tests of possible relations between eye movement and deferred imitation data. In the 12-month-old sample (Experiment 3), the amount of newly acquired functional target actions [3] and all gaze variables concerning Functional Target Action POIs and Talking POIs were transformed into dichotomous variables via median split and analyzed by χ^2 tests. None of the tests led to a significant result, indicating that there was no relation between the gaze variables and the imitation score of functional target actions. An analysis of biserial correlations between the gaze variables and the amount of newly acquired functional target actions, independent samples t tests with the factor high vs. low amount of newly acquired functional target actions, as well as an analysis of logistic regression led to the same conclusion.

In the 18-month-old sample (Experiment 4), correlation coefficients between the amount of newly acquired functional and arbitrary target actions and gaze variables (fixation times to the Face AOI resp. Action AOI, as well as the amount of saccades between these AOIs during Functional and Arbitrary Target Action POIs and Talking POIs) were calculated. The amount of newly acquired functional target actions did not correlate with any of the gaze variables. In contrast, the amount of newly acquired arbitrary target actions correlated with fixation times to the Face AOI during Talking POIs, as well as with fixation times to the Action AOI during both Functional and Arbitrary Target Action POIs. This shows that infants' eye movements were not related to their overall target action performance, but only to the acquisition of new arbitrary target actions.

Findings of Experiments 3 and 4 strengthen the position that selective imitation cannot be explained by selective visual attention (Esseily & Fagard, 2012; Kirkorian et al., 2012). However, even though selective imitation of a specific kind of target actions does not seem to rely on increased visual attention towards this kind of action during the demonstration phase, visual attention still might play a role in infants' imitation.

2.5.5. Inter-individual Differences in Gaze Behavior and Deferred Imitation

As described above, the group means of 18-month-old infants in Experiment 4 showed that infants acquired both kinds, but significantly more functional than arbitrary target actions from the demonstration. Taking a look at individual infants' performance it can

[3] Due to the very low - not different from zero - amount of newly acquired arbitrary target actions analyses concerning this variable were omitted.

be seen that not all infants showed this pattern: some infants only acquired functional target actions. Thus, some infants imitated selectively, similar to 12-month-olds, and others imitated more exactly. There can be several reasons why infants showed this kind of inter-individual variability (see Section 1.4). To address this question, two subsamples of 18-month-olds were compared in a post-hoc analysis: one subsample consisted of infants who acquired only functional target actions from the demonstration (*selective imitators*, $n = 8$), and the other subsample consisted of infants who acquired both functional and arbitrary target actions (*exact imitators*, $n = 9$). A third subsample, consisting of three infants who did not acquire any functional target actions, was not included in this analysis due to small sample size. For the purposes of this analysis, two new variables were computed: the total amount of on-screen fixations as a general measure of infants' attention to the video, and the mean length of fixations during the total video presentation, which was found to be related to information processing and memory performance in previous studies (Colombo, Mitchell, & Horowitz, 1988; Kirkorian, 2007). Gaze behavior and target action performance of selective imitators vs. exact imitators were compared by a series of one-way ANOVAs, which yielded a specific pattern of differences in gaze behavior, but not in target action performance. The absence of differences between the subsamples in target action performance indicates that exact imitators did not imitate more functional target actions, nor did they perform more target actions in the baseline phase than selective imitators. Additionally, no differences were found between the subsamples in gaze behavior in general, such as the amount of on-screen fixations or mean fixation length. Instead, a specific pattern of differences was observed. During Talking POIs, exact imitators had longer fixation times to the Face AOI and more saccades between the Face AOI and the Action AOI than selective imitators. During both Functional and Arbitrary Target Action POIs, exact imitators had longer fixation times to the Action AOI than selective imitators, while fixation times to the Face AOI, as well as the amount of saccades between the two AOIs did not differ between subsamples.

Interpreting these findings in the framework suggested by the theory of natural pedagogy (Csibra & Gergely, 2006, 2009), exact imitators' longer fixation times to the Face AOI during Talking POIs showed their stronger sensitivity to the model's ostensive cues, and at the same time, their larger number of saccades between the model's face and the object suggested that they participated more actively than selective imitators in this joint-attention-like episode with the model. This participation enabled exact imitators to follow the model's cues about the "new and relevant information" (Csibra & Gergely, 2006), i.e. the target actions to be demonstrated more closely, as evidenced by longer fixation times to the Action AOI during the demonstration of both kinds of target actions. Thus, exact imitators had a better chance than selective imitators to encode both kinds of target actions. However, this advantage was only reflected in the amount of arbitrary, but not functional, target actions acquired from the action demonstration video. These findings support the idea that sensitivity to and involvement in the social-communicative context of imitation facilitates more exact imitation (e.g., Gergely & Király, 2003), i.e., in this case, imitation of not only functional, but also arbitrary target actions.

2.6. Conclusions

The series of experiments constituting the present dissertation aimed at integrating two paradigms of imitation research, namely memory-oriented deferred imitation research and research on selective imitation in order to tackle the relations between quantitative and qualitative changes in infants' imitation. The procedure of the experiments relied on deferred imitation studies (e.g., Kolling et al., 2010), while the systematic variation of target action type was adopted from immediate imitation studies on selective imitation (e.g., Carpenter, Akhtar, & Tomasello, 1998).

Results of Experiments 1 and 2 showed that 12- and 18-month-olds' deferred imitation performance not only differed in respect to performance rates, as found by earlier deferred imitation studies (Barr et al., 1996; Hayne et al., 2000; Kolling et al., 2010), but also in the pattern of their target action reproduction, consistently with findings on selective imitation (e.g., Nielsen, 2006). 12-month-olds' deferred imitation was selective (memory effect only for functional target actions), whereas 18-month-olds' deferred imitation was more exact (memory effect also for arbitrary target actions). This finding has consequences for both selective imitation and deferred imitation research. On the one hand, preferential imitation of functional target actions in a deferred imitation test should be considered in terms of item difficulty. The present findings suggest that functional target actions are easier items of a memory test than arbitrary ones. This should be kept in mind primarily when comparing declarative memory performance of different age groups, as 18-month-olds might imitate the more difficult target actions due to other reasons than memory advantage. On the other hand, since most studies on selective imitation have applied an immediate imitation paradigm and have not tested long-term retention of different kinds of target actions, the present findings complement these studies with a temporal perspective. The findings of Experiment 2 revealed that 18-month-olds are able to recall some arbitrary target actions after a delay, thus their ability to reproduce different kinds of target actions is not restricted to immediate imitation. In addition, the parallel forgetting rates of functional and arbitrary target actions in Experiment 2 indicate that action selection takes place at an early stage of the imitation process and the two kinds of target actions are affected by long-term retention in a similar way.

All of the main findings concerning the deferred imitation tests after 30 minutes were replicated by Experiments 3 and 4, even though these later experiments involved a video demonstration of target actions. Thus, the main findings on the role of selective imitation processes in deferred imitation are based on four experiments and a total sample of 105 infants.

In Experiments 3 and 4 the deferred imitation method was combined with eye tracking. Results concerning the main research question of these experiments demonstrated that infants' fixation times to the Action AOI did not vary according to target action functionality in either of the two age groups. This suggests that selective imitation, as evidenced by higher imitation rates of functional than arbitrary target actions in both age groups, cannot be explained by selective visual attention towards functional as opposed to arbitrary target actions. This finding is an important contribution to the theories of selective imitation, as both lower-level (for an exception see Beisert et al., 2012) and higher-level theories implicitly presume that infants watch and encode all target actions. According to the direct matching theory, target actions to be imitated are selected by a mechanism that maps the observed action on the infant's own motor repertoire, as well as by action-effect binding (Paulus et al., 2011a, 2011b). As a result, a target action will only be imitated if it can be mapped onto the infant's motor repertoire and if it was followed by a salient effect that the infant is willing to try to reach her- or himself. Contrary to this, higher-level theories claim that target actions to be imitated are selected by different action interpretation mechanisms, such as teleological interpretation in younger infants and mentalizing interpretations in older ones (Gergely, 2003). Thus, both theories suggest that the selection of target actions is guided by different processes beyond visual attention. The common finding of Experiments 3 and 4 strengthens this position. However, it does not favor either of the two theories.

Additional analyses of infants' eye movements during target action observation suggested that infants in both age groups successfully oriented their visual attention to the relevant information on the screen. Age differences in looking behavior were also found, as 12-month-olds looked longer to the object than to the model's face while the model was talking, whereas 18-month-olds did not show this difference. This is consistent with the different motivational backgrounds attributed to younger vs. older infants: younger infants are thought to participate in imitation tasks primarily with a cognitive motivation to learn about new objects, while older infants are thought to have a stronger social motivation (Uzgiris, 1981). Furthermore, 18-month-olds', but not 12-month-olds' gaze switches between the object and the model's face indicated a joint-attention-like episode between the model and the infants (with shared focus on the target object), as well as infants' looking for a cue about the ongoing arbitrary actions in the model's face (cf. Vivanti et al., 2008).

Further exploration of the social aspects of Experiment 4 was enabled by 18-month-olds' neither completely selective, nor completely exact imitation. Post-hoc analyses of inter-individual differences between selective imitators and exact imitators yielded new insights into the relations between gaze behavior and deferred imitation. A specific pattern of differences between the two subsamples' eye movements suggests that infants' imitative behavior was affected by the social-communicative context of the imitation task. More importantly, while previous studies established this effect by varying the degree of the model's social availability (Király, 2009; Nielsen, 2006; Nielsen et al., 2008), the findings of Experiment 4 are the first to indicate that infants' attention to the social-communicative context of the ongoing imitation task affects what they learn during target action demonstration. Infants who showed more attention to the model's social-communicative cues and also followed these cues more efficiently learned not only functional, but also arbitrary target actions from the model. Infants who showed less attention to the model's cues and looked less to the target actions were also able to acquire new target actions from the demonstration and thus engage in deferred imitation. These infants, however, learned only functional target actions, which are more closely linked to the action-related objects than arbitrary ones. This finding suggests that higher, rather than lower-level processes guide selective imitation. However, the question whether exact imitators' increased attention to the model's social-communicative cues in the present study relied on stable processes or situational constraints remains open for future research.

There are some critical aspects of the present work that have to be acknowledged. First, none of the experiments involved an immediate imitation test, which could have been useful in bridging selective imitation and deferred imitation processes more directly. However, previous research has demonstrated selective imitation in 12-month-olds and more exact imitation in 18-month-olds in immediate imitation paradigms (e.g., Nielsen, 2006). Additionally, parallel forgetting rates between the two deferred imitation tests in Experiment 2 also allow the assumption that forgetting rates would have been parallel between an immediate imitation test and the deferred imitation test after 30 minutes, too. Second, target action functionality was conceptualized in a new way. Instead of varying only one function-related feature, such as intentionality or action effects, functional actions were defined in a more general way, as actions that require specific object properties. Arbitrary actions, in contrast, could be performed on a wide range of objects. Resulting from this definition, functional target actions showed some diversity with respect to their effects, which could have made some of the functional target actions more difficult to imitate than others. In fact, imitation rates of both functional and arbitrary target actions showed some variation across items in all experiments. Nevertheless, this variation could have resulted, at least partly, also from the varying attractiveness of the objects. In addition, a variation in item difficulty in multi-item deferred imitation tests is not unusual (Abranavel & Gingold, 1985; Goertz et al., 2006, 2008). The third critical aspect of the present work is that the target action demonstration videos in Experiments 3 and 4 showed a natural demonstration phase as known from deferred imitation studies. This can be seen both as a virtue and as a weakness of the applied method. On the one hand, it ensures higher ecological validity and makes the findings directly relevant to deferred imitation research. On the other hand, it results in AOIs that differ in size and POIs that differ in length. Although the correction of gaze variables (as described in Section 2.4.4) compensates for this variability, a more standardized action demonstration video might yield clearer, less biased data. And last, although Experiment 4 delivered interesting new findings on the social-communicative context of imitation from infants' point of view, this analysis was post hoc and thus the size of subsamples was low. Additionally, the model's social availability was not varied in this experiment. Future research should combine a variation of the model's social-communicative cues (e.g., talking model vs. silent model) and a post hoc analysis of selective imitators vs. exact imitators to provide more detailed explanation of how the social-communicative context affects infants' imitation.

Despite these limitations, the present experiments are a valuable contribution to the research on infants' imitation, as they yield new insights into deferred imitation and selective imitation processes, as well as the relations between visual attention during action observation and subsequent imitation. The present dissertation project is innovative, as it combines imitation paradigms (deferred imitation tests assessing both memory performance and selective imitation) with eye tracking, thus investigating the two most important ways of infants' learning, namely looking and imitating, at the same time.

3
Zusammenfassung

3.1. Imitationsparadigmen in der entwicklungspsychologischen Forschung

Imitation ist einer der wichtigsten Lernmechanismen im Säuglings- und Kleinkindalter, der bereits kurz nach der Geburt nachweisbar ist (z.B., Field et al., 1982; Meltzoff & Moore, 1977, 1983). Imitation bei Säuglingen und Kleinkinder wird in verschiedenen Bereichen der entwicklungspsychologischen Forschung untersucht. Abhängig von der genauen Fragestellung werden dabei einzelne Aspekte des Designs variiert, die grundlegende Methode bleibt aber die selbe. Zunächst beobachten Kinder, wie ein Modell die Zielhandlungen ausführt (*Demonstrationsphase*). Anschließend, entweder gleich nach der Demonstrationsphase oder nach einer Verzögerungsphase, werden die Objekte, an denen die Zielhandlungen demonstriert wurden, den Kindern zum Spielen angeboten (*Abrufphase*). Um die spontane Zielhandlungsausführung zu erfassen, wird entweder eine Kontrollgruppe, die die Zielhandlungen nicht beobachtet hat, oder eine Basisratenerhebung vor der Demonstrationsphase eingesetzt. Insofern die Anzahl ausgeführter Zielhandlungen in der experimentellen Gruppe bzw. in der Abrufphase die Anzahl ausgeführter Zielhandlungen in der Kontrollgruppe bzw. in der Basisrate signifikant übersteigt, spricht man von (verzögerter) Imitation (Meltzoff, 1985, 1988).

3.1.1. Erfassung von Gedächtnisleistungen

Die experimentelle Methode der Verzögerten Imitation ist der am häufigsten eingesetzte Test zur Erfassung deklarativer Gedächtnisleistungen im Säuglingsalter. Säuglinge sind bereits ab dem 6. Lebensmonat in der Lage, eine geringe Anzahl von objektbezogenen Handlungen nach einer Verzögerungsphase von bis zu 24 Stunden zu imitieren (Barr et al., 1996; Collie & Hayne, 1999; Heimann & Nilheim, 2004; Kressley-Mba et al., 2005). Darüber hinaus zeigt sich, dass die verzögerte Imitationsleistung mit zunehmendem Alter steigt. Zum einen imitieren ältere Kinder mehr Zielhandlungen als jüngere Kinder (Barr et al., 1996; Collie & Hayne, 1999; Elsner et al., 2007; Kolling et al., 2010). Zum anderen behalten ältere Kinder die Zielhandlungen über längere Zeiträume als jüngere Kinder (Barr & Hayne, 2000; Carver & Bauer, 2001; Herbert et al., 2006; Herbert & Hayne, 2000b). Im Weiteren zeigen ältere Kinder auch nach wenigeren Demonstrationsdurchgängen einen Gedächtniseffekt (e.g., Barr et al., 1996). Diese altersabhängige, quantitative Entwicklung der verzögerten Imitation wird mit zunehmenden Gedächtnisleistungen erklärt (z.B., Bauer, 2005; Hayne, 2004; Jones & Herbert, 2006; Knopf et al., 2011).

3.1.2. Erfassung vom Handlungsverständnis

Anhand von Imitationsstudien kann auch das kindliche Handlungsverständnis untersucht werden. Statt eines langfristigen Behaltens von Zielhandlungen steht in diesen Studien die Frage im Mittelpunkt, wie Kinder die beobachteten Handlungen wahrnehmen und interpretieren. Deshalb wird in diesem Bereich meistens direkte Imitation (ohne Verzögerungsphase) angewendet. Imitationsstudien in diesem Bereich zeigten, dass Kinder im Alter von ungefähr einem Jahr nicht alle Zielhandlungstypen gleich häufig imitieren. Zum Beispiel imitieren Kinder Handlungen, die scheinbar absichtlich ausgeführt wurden häufiger als Handlungen, die scheinbar zufällig ausgeführt wurden (Carpenter, Akhtar, & Tomasello, 1998). Handlungen, die nötig sind um das Handlungsziel zu erreichen, werden häufiger imitiert als Handlungen, die für das Ziel nicht nötig sind (Brugger et al., 2007). Darüber hinaus werden Handlungen, die in der aktuellen Situation als effizient erscheinen, häufiger imitiert als Handlungen, die nicht als effizient erscheinen (Gergely et al., 2002; Schwier et al., 2006). Im Gegensatz zur selektiven Imitation bei Einjährigen imitieren Zweijährige die Zielhandlungen des Modells exakt, auch wenn das Weglassen mancher Handlungsschritte dazu führen würde, dass das Handlungsziel effizienter erreicht wird (Nagell et al., 1993; Nielsen, 2006). Da Anderthalbjährige ein Imitationsverhalten zeigen, das weder als ganz selektiv, noch als ganz exakt bezeichnet werden kann (Nielsen, 2006; Tennie et al., 2006), ist dieser Altersunterschied wahrscheinlich keine plötzliche Veränderung, sondern eher die Folge einer stufenweise Entwicklung.

Obwohl manche Theorien automatische Prozesse als die Grundlage von selektiver vs. exakter Imitation annehmen (Hauf & Prinz, 2005; Meltzoff, 2007; Paulus et al., 2011a, 2011b), kann der Altersunterschied durch höhere kognitive Prozesse besser erklärt werden. Gergely (2003) beschreibt eine altersbedingte Änderung in den Handlungsinterpretationen der Kinder, wobei jüngere Kinder die Handlungen im Hinblick auf deren Resultat und situative Gegebenheiten interpretieren, während ältere Kinder die Demonstration von Zielhandlungen als eine pädagogische Episode auffassen. Diese Verschiebung von objektzentrierter zu sozialer Imitation wird von Uzgiris (1981) damit erklärt, dass jüngere Kinder in erster Linie motiviert sind, über Objekte und deren Funktionen zu lernen, während bei älteren Kindern soziale Motivationen auch eine Rolle spielen. Die Rolle des sozialen Kontextes wurde von mehreren Studien bestätigt, die zeigten, dass Kinder umso exakter imitieren, je mehr Interaktion mit dem Modell möglich ist (Király, 2009; Nielsen, 2006; Nielsen et al., 2008).

3.1.3. Erfassung von Kategorisierung und Lernen über Objekte

Obwohl das Lernen von Handlungen im Mittelpunkt der meisten Imitationsstudien steht, lernen Kinder durch Imitation nicht nur etwas über die Zielhandlungen, sondern auch etwas über die Objekte (e.g., Elsner & Pauen, 2007). Sie sind auch in der Lage, die gesehenen Zielhandlungen auf neue Objekte zu übertragen (Barnat et al., 1996; Bauer & Dow, 1994; Hayne et al., 1997; Herbert & Hayne, 2000a). Dies zeigt, dass Kinder die funktionelle Ähnlichkeit zwischen dem Demonstrationsobjekt und dem Testobjekt erkennen und daraus folgern, dass das Testobjekt auch geeignet ist, um die gesehene Zielhandlung auszuführen. Trotz dieser Befunde, die zeigen, dass Kinder durch Imitation auch über Objektfunktionen lernen, wurden die Effekte der Handlungsfunktionalität auf die Imitationsleistung von Kindern bisher nicht systematisch untersucht.

3.2. Ziele und Methode der vorliegenden Experimente

Wie eingangs beschrieben, ändert sich die Imitationsleistung im zweiten Lebensjahr sowohl quantitativ als auch qualitativ. Die quantitative Änderung wird der Entwicklung des Gedächtnisses zugeschrieben (Barr et al., 1996; Elsner et al., 2007; Kolling et al., 2010), während die qualitative Änderung mit Änderungen der Handlungsinterpretation und der Motivation erklärt wird (Gergely, 2003; Uzgiris, 1981). Diese Prozesse sind aber wahrscheinlich nicht unabhängig voneinander. Einerseits ist es möglich, dass die Enkodierung und der Abruf von Zielhandlungen, die in der selektiven Imitation jüngerer Kinder weggelassen werden (z.B. Handlungen ohne Effekt), schwieriger sind. Effizientere Informationsverarbeitungs- und Gedächtnisprozesse von älteren Kindern könnten dazu führen, dass sie auch diese, schwierigeren Handlungen imitieren. Andererseits ist es auch möglich, dass Änderungen der Handlungsinterpretation und Motivation, die zu exakter Imitation führen, auch für die quantitative Entwicklung von Imitation verantwortlich sind. Kinder, die exakter imitieren, imitieren mehr Handlungstypen und dadurch auch mehr Zielhandlungen als Kinder, die selektiv imitieren. Die Zusammenhänge dieser Prozesse sind jedoch noch ungeklärt.

Ziel der vorliegenden Experimente war es, zwei Bereiche der Imitationsforschung, nämlich die Gedächtnisforschung durch Verzögerte Imitation und die Erforschung des kindlichen Handlungsverständnisses und der selektiven Imitation näher zusammenzubringen und dadurch die Zusammenhänge zwischen quantitativen und qualitativen Veränderungen des Imitationsverhaltens zu untersuchen. Deshalb wurde in den vorliegenden Experimenten das Imitationsverhalten 12 und 18 Monate alter Kinder mit verzögerten Imitationstests, in denen die Zielhandlungen systematisch variiert wurden, untersucht (Artikel 1). Da das Lernen über Objekte und deren Funktionen eines der wichtigsten Ziele von Imitation ist (Uzgiris, 1981), wurden in den Experimenten funktionale vs. arbiträre Handlungen variiert. Funktionale Handlungen sind solche, die mit der aktuellen Funktion des Objektes stark verknüpft sind und spezifische Objekteigenschaften voraussetzen, während arbiträre Handlungen mit jedem beliebigen Objekt ausgeführt werden können.

Im Weiteren wurde der Frage nachgegangen, welche Prozesse selektive Imitation bedingen. Unabhängig davon, ob höhere kognitive Prozesse im Hintergrund von selektiver Imitation angenommen werden, oder selektive Imitation mit automatischen Prozessen erklärt wird, gehen alle Theorien (für eine Ausnahme s. Beisert et al., 2012) davon aus, dass Kinder alle demonstrierten Zielhandlungen beobachten und die Selektion erst in einem weiteren Schritt stattfindet. Jedoch wurden Zusammenhänge der visuellen Aufmerksamkeit, die Kinder verschiedenen Handlungstypen schenken und der nachfolgenden Imitation dieser Handlungstypen bisher nicht untersucht. Daher wurde in der Hälfte der Experimente die Methode der Verzögerten Imitation mit Eye Tracking kombiniert, um sowohl die Imitationsleistung als auch das Blickverhalten der Kinder zu erfassen (Artikel 2 und 3).

3.3. Befunde der vorliegenden Arbeit

3.3.1. Selektive verzögerte Imitation

Sowohl 12 Monate alte (Experiment 1), als auch 18 Monate alte Kinder (Experiment 2) führten in den Testphasen signifikant mehr Zielhandlungen aus, als in der Basisrate – sie zeigten also einen Gedächtniseffekt, was frühere Befunde über verzögerte Imitation repliziert (Barr et al., 1996; Kolling et al., 2009). 18 Monate alte Kinder zeigten in der zweiten Testphase nach zwei Wochen weiterhin einen Gedächtniseffekt, allerdings mit niedrigeren Imitationsraten als nach der 30-minütigen Verzögerung, was auf Vergessen hinweist (cf. Bauer et al., 2000; Klein & Meltzoff, 1999).

Neben dem Gedächtniseffekt zeigte sich auch ein Funktionalitätseffekt: Kinder in beiden Altersgruppen imitierten mehr funktionale als arbiträre Zielhandlungen. Im Weiteren zeigte sich ein Alterseffekt: 12 Monate alte Kinder imitierten nur funktionale Handlungen, d.h. nur für diese Handlungen zeigte sich ein Gedächtniseffekt, während 18 Monate alte Kinder beide Handlungstypen imitierten, wobei die Imitationsrate funktionaler Handlungen höher war. Diese Befunde über selektive Imitation bei 12 Monate alten und etwas exaktere Imitation bei 18 Monate alten Kindern sind ebenfalls konsistent mit früheren Befunden (Nielsen, 2006; Tennie et al., 2006). Bei den 18 Monate alten Kindern (Experiment 2) nahmen die Imitationsraten von funktionalen und arbiträren Handlungen zwischen den zwei Testzeitpunkten parallel ab. Dies deutet darauf hin, dass selektives Vergessen keine Rolle im Hinblick auf selektive Imitation spielt, die Selektion der zu imitierenden Handlungen muss also in einer früheren Phase des Wahrnehmungs- und Gedächtnisprozesses stattfinden.

Diese Ergebnisse liefern neue Erkenntnisse für die Erforschung von sowohl verzögerter, als auch selektiver Imitation. Zum einen zeigt der Funktionalitätseffekt, dass funktionale Handlungen einfachere Testitems sind als arbiträre, aber auch, dass 18 Monate alte Kinder diese häufiger imitieren als 12 Monate alte. Beim Vergleich der verzögerten Imitationsleistung verschiedener Altersgruppen muss also berücksichtigt werden, dass die höhere Leistung älterer Kinder nicht nur durch ihre bessere Gedächtnisleistung, sondern auch durch altersabhängige Änderungen in selektiver vs. exakter Imitation bedingt werden kann. Zum anderen erweitern die vorliegenden Experimente die bisherige Forschung über selektive Imitation mit einer zeitlichen Perspektive. Die Ergebnisse von Experiment 2 zeigen, dass 18 Monate alte Kinder in der Lage sind arbiträre Handlungen auch nach einer Verzögerung zu imitieren, ihre Imitation von verschiedenen Handlungstypen beschränkt sich also nicht auf direkte Imitation. Das Imitationsverhalten von Kindern in den Eye Tracking Experimenten 3 und 4 replizierte sowohl den Gedächtnis- als auch den Funktionalitätseffekt sowie die unterschiedlichen Imitationsmuster in den zwei Altersgruppen.

3.3.2. Blickbewegungen während der Beobachtung von Zielhandlungen

Die zentrale Frage der Experimente 3 und 4 war, ob Kinder den funktionalen Zielhandlungen während der Demonstrationsphase mehr Aufmerksamkeit schenken als den arbiträren Zielhandlungen, also ob selektive Imitation funktionaler Handlungen mit selektiver visueller Aufmerksamkeit erklärt werden kann. Im Experiment 3 zeigte sich kein Unterschied zwischen den Blickzeiten auf funktionalen vs. auf arbiträren Zielhandlungen. Im Experiment 4 waren die Blickzeiten auf arbiträren Zielhandlungen insgesamt länger als auf funktionalen Zielhandlungen, dieser Unterschied konnte jedoch mit Itemeffekten erklärt werden. Insgesamt zeigten also die Blickdaten beider Experimente, dass die Blickzeiten nicht von der Funktionalität der beobachteten Zielhandlungen abhängig waren.

3.3.3. Zusammenhänge zwischen Handlungsbeobachtung und verzögerter Imitation

Befunde der verzögerten Imitation und des Blickverhaltens beider Altersgruppen haben gezeigt, dass Kinder mehr funktionale als arbiträre Zielhandlungen imitierten, obwohl sie während der Demonstrationsphase den funktionalen Handlungen nicht mehr Aufmerksamkeit schenkten als den arbiträren. Der Effekt der Funktionalität auf die verzögerte Imitationsleistung war über die Items hinweg konsistent. Blickzeiten auf verschiedene Zielhandlungen wurden hingegen nicht durch die Funktionalität, sondern vielmehr durch die Eigenschaften der einzelnen Items beeinflusst. Dieser Kontrast zeigt, dass selektive Imitation funktionaler Handlungen nicht mit selektiver Aufmerksamkeit auf diese Handlungen erklärt werden kann. Dies wurde mit statistischen Verfahren, die den Zusammenhang zwischen Blick- und Imitationsverhalten direkt prüften (Chi-Quadrat Tests, T-Tests, Korrelationen, Regressionsanalyse), bestätigt.

Obwohl keine allgemeinen Zusammenhänge zwischen Blick- und Imitationsverhalten gefunden wurden, zeigten die Befunde der Gruppe von 18 Monate alten Kindern ein differenzierteres Bild. Analysen von Korrelationen sowie eine post-hoc Analyse zweier

Subgruppen deuteten darauf hin, dass nicht die gesamte Imitationsleistung, sondern nur die Imitation arbiträrer Zielhandlungen mit dem Blickverhalten zusammenhängt. Während das Modell sprach, schauten Kinder, die sowohl funktionale als auch arbiträre Zielhandlungen imitierten („exakte Imitierer“) länger auf den Gesichtsbereich und hatten mehr Sakkaden zwischen dem Gesichtsbereich und dem Handlungsbereich als Kinder, die ausschließlich funktionale Zielhandlungen imitierten („selektive Imitierer“). Während die Zielhandlungen demonstriert wurden, schauten exakte Imitierer länger auf den Handlungsbereich als selektive Imitierer. Diese Befunde lassen sich im Rahmen der Theorie der natürlichen Pädagogik (Csibra & Gergely, 2006, 2009) interpretieren. In diesem Sinne schenkten exakte Imitierer dem sozial-kommunikativen Kontext dieser Imitationsaufgabe mehr Aufmerksamkeit als selektive Imitierer und folgten den Cues des Modells über die „neue und relevante Information“ (Csibra & Gergely, 2006), also die Zielhandlungen, effizienter. Infolge dessen schenkten sie den demonstrierten Zielhandlungen mehr Aufmerksamkeit und hatten bessere Chancen diese zu enkodieren. Dieser Vorteil zeigte sich aber nur in der Anzahl neu gelernter arbiträrer, aber nicht in der Anzahl neu gelernter funktionaler Zielhandlungen. Dies deutet darauf hin, dass erhöhte Aufmerksamkeit auf den sozial-kommunikativen Kontext die exakte Imitation von Zielhandlungen begünstigen kann.

3.4. Diskussion

Im vorliegenden Dissertationsprojekt wurden Imitationstests zur Erfassung von selektiver sowie verzögerter Imitation eingesetzt und damit zwei Paradigmen der Imitationsforschung kombiniert. Die Ergebnisse liefern neue Erkenntnisse für beide Paradigmen und legen dar, dass die Imitationsleistung von Kleinkinder sowohl durch selektive Imitation, als auch durch die der verzögerten Imitation zugrunde liegenden Gedächtnisprozesse bestimmt wird. Im Weiteren wurden die Imitationstests mit Eye Tracking kombiniert, um Zusammenhänge zwischen Handlungswahrnehmung und Imitation zu untersuchen. Die Ergebnisse der Eye Tracking Experimente deuten zwar darauf hin, dass selektive Imitation nicht durch selektive visuelle Aufmerksamkeit auf eine bestimmte Art von Zielhandlung erklärt werden kann. Feinere Analysen der Blick- und Imitationsdaten 18 Monate alter Kinder deuteten aber auf Zusammenhänge zwischen der Verteilung der visuellen Aufmerksamkeit während der Beobachtung der Zielhandlungsdemonstrationen und der Ausprägung der selektiven Imitation hin. Aus diesen Befunden lässt sich schließen, dass die Kombination von Imitations- und Eye Tracking Paradigmen eine vielversprechende neue Richtung der Forschung ist, die wertvolle Impulse für weitere Untersuchungen liefert.

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A

Dissertation-Relevant Manuscripts

Paper 1

Óturai, G., Kolling, T., Rubio Hall, L., & Knopf, M. (2012). The role of object functions for deferred imitation – Do infants selectively retain and forget target actions? *Infant Behavior and Development, 35*, 195-204.

Paper 2

Kolling, T., Óturai, G., & Knopf, M. (in press). Is selective attention the basis for selective imitation in infants? An eye-tracking study of deferred imitation with 12 month-olds. *Journal of Experimental Child Psychology.*

Paper 3

Óturai, G., Kolling, T., & Knopf, M. (2013). Relations between 18-month-olds' gaze pattern and target action performance: A deferred imitation study with eye tracking. *Infant Behavior and Development, 36*, 736-748.

Paper 1

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The role of object functions for deferred imitation – Do infants selectively retain and forget target actions?

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Selective imitation

ABSTRACT

The present study investigated the effect of target action functionality (functional vs. arbitrary actions) on 18- and 12-month-old infants' deferred imitation performance. While 18-month-olds' deferred imitation performance was assessed after a short (30 min) and after a long (2 weeks) delay, only the short delay was realized in 12-month-olds. Besides replicating the well established memory effect for both age groups, that is, an improved performance level of target actions in all memory tests as against to a baseline phase, a functionality effect was found, indicating that infants of both age groups imitated significantly more functional than arbitrary target actions. The rate of forgetting of target actions between the first and the second memory assessment was similar for functional and arbitrary actions, demonstrating that the forgetting process is not specific for the two types of target actions. Implications of the findings for both imitation and memory theories as well as for memory test construction are discussed.

1. Introduction

Observing and re-enacting, i.e., imitating other people's behavior is probably the most important learning mechanism for infants, toddlers and young children. Through imitative processes infants both acquire knowledge about objects and actions and maintain social interactions (Uzgiris, 1981). In his classical studies, Meltzoff (1985, 1988) introduced a standardized experimental procedure to assess immediate and deferred imitation processes in preverbal infants and toddlers. In this experimental paradigm, the infant observes a model performing novel actions on one or a series of unfamiliar objects. Either immediately or following a delay of minutes, hours, days or even weeks the infant has the possibility to play with the objects. Then, the amount of performed target actions is assessed. In a between-subjects design, the average number of target actions performed by children in an experimental group (demonstration of target actions) is compared to the number of performed target actions in a control group (no demonstration) in order to separate effects driven by imitative processes from (pre)knowledge. Alternatively, in a within-subjects design, baseline and memory performance are assessed within the same group of infants: prior to the demonstration of target actions, children are given the target objects in a baseline phase and their spontaneous playing behavior is observed. A larger amount of target action performance in the experimental group as compared to the control group (between-subjects design), or in the test phase compared to the baseline phase (within-subjects design) is interpreted as (deferred) imitation.

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Several studies (e.g., Carpenter, Call, & Tomasello, 2005; Király, 2009; Meltzoff, 1995) demonstrated that children do not necessarily blindly imitate what they observe but weight the target actions, a phenomenon labeled selective imitation.[1] Carpenter et al. (2005), for example, showed that infants can switch between imitating the precise action vs. imitating the action's end state, depending on the salience of the end state. If the action (moving a mouse on a table) ended on a salient location (in a house), 12- and 18-month-old infants were more likely to move the object directly there, interpreting the location as the goal. In contrast, infants were more likely to perceive the style of the motion as the goal and to copy the motion when the action just ended somewhere on the table without any salient cue. Nielsen (2006) additionally demonstrated that both the apparent logic of the model's behavior and the social-communicative context had a differential effect on imitation performance in different age groups. Specifically, the author showed that 18-month-olds were as likely to copy the model's precise actions as to copy the action's outcome. In contrast, 12-month-old infants only imitated the model's precise actions if the logic of the actions was apparent. In the sense of Uzgiris' (1981) theory about the two functions of imitation, these findings indicate that one-year-olds are mainly motivated to learn about object functions, whereas 18-month-olds start to become sensitive to the social-interactive setting of imitation as they imitate more precisely in order to maintain the interaction with the model.

Up to now, selective imitation processes have rarely been taken into account in deferred imitation studies which focus on assessing declarative memory in infants and children. In this memory research program it has been demonstrated that infants already show deferred imitation at the age of six months. The number of imitated target actions in six-month-olds, however, is low and the maximum length of retention interval was reported to be 24 h (Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999; Heimann & Nilheim, 2004; Kressley-Mba, Lurg, & Knopf, 2005). Both cross-sectional (e.g., Barr et al., 1996; Meltzoff, 1985) and longitudinal studies (e.g., Kolling, Goertz, Frahsek, & Knopf, 2010; Nielsen & Dissanayake, 2004) demonstrated that deferred imitation performance improves with age. Studies with infants from different age groups report that older infants reproduce more target action steps than younger ones after the same retention interval (Barr et al., 1996; Collie & Hayne, 1999; Elsner, Hauf, & Aschersleben, 2007; Goertz, Kolling, Frahsek, & Knopf, 2008; Kolling et al., 2010). Studies varying the length of the retention interval, on the other hand, indicate that older children exhibit deferred imitation after longer retention intervals than younger ones (Herbert & Hayne, 2000a; Barr & Hayne, 2000). From the age of 12 months onwards, for example, infants can retain target actions over retention intervals of several days and even longer (e.g., Klein & Meltzoff, 1999). However, deferred imitation performance is sensitive to contextual changes (Hayne, Boniface, & Barr, 2000), item-relational information (Knopf, Kraus, & Kressley-Mba, 2006) and target action structure. Bauer and Mandler (1989), for example, found that children as young as 16 months are sensitive to the causal structure of target action sequences. Infants recalled enabling action sequences more frequently in the right temporal order than arbitrary ones. This effect was found both in immediate and in deferred imitation experiments. Elsner et al. (2007) analyzed 9- to 15-month-old infants' reproduction of a multi-step target action and found evidence for infants' sensitivity to action-effect relations. In contrast to studies by Barr et al. (1996), in which the second step of a three-step action sequence lead to the outcome, Elsner et al. (2007) used a three-step action sequence with the last step leading to an outcome. Infants in this study had a higher imitation rate (especially of the third action step) than infants in the Barr et al. study. This finding suggests that infants encoded and retained action-effect relations.

The findings reported so far show that imitation performance is significantly influenced by the demonstrated target actions. Although a number of imitation studies varied factors usually coinciding with functional object use, i.e., intentionality (Carpenter, Akhtar, & Tomasello, 1998) or action effects (Elsner et al., 2007), they did not discuss thoroughly that infants learn something about object functions and affordances when imitating a model. There are some hints, however, that infants can learn about object functions via imitation (Elsner & Pauen, 2007) and that they are able to generalize this knowledge to novel, similar objects (Barnat, Klein, & Meltzoff, 1996; Bauer & Dow, 1994; Hayne, McDonald, & Barr, 1997; Herbert & Hayne, 2000b). To our knowledge, systematic effects of target action functionality, however, have never been described in deferred imitation research. Understanding effects of target action functionality is not only important for selective imitation processes, but also centrally relevant for infants' memory performance. It is reasonable to assume that target action functionality influences infants' memory performance level. To study these effects, the present study investigated infants' retention and forgetting of target actions with varying functionality in a deferred imitation task.

Action functionality in this study was defined in accordance with a multi-component theory of object function (Chaigneau, Barsalou, & Sloman, 2004). According to this theory, object function is not a single feature, but rather a complex set of function-related knowledge, including physical properties, the settings in which the object can usually be found, and the actions that can be performed with the object. As effects of action functionality cannot be assessed by varying only one function-related factor, we used a multi-item deferred imitation test (Kolling et al., 2010). The functions of the objects in our tests could be discovered by the infants in different ways: some functional actions lead to a sound effect, others lead to a visible end state, and some others presented the object's conventional function. Generally, functional actions always rely

[1] Selective imitation studies theoretically rely on the emulation/imitation debate. Conflicting definitions have been brought forward by different research groups. One definition implies that imitation is a more insightful form of learning, as it involves copying of both actions and action outcomes. Another definition implies that emulation is more insightful, as the observer understands the action goal and adjusts the observed action to his or her situational constraints to reach the goal (for a review see Want & Harris, 2002). This terminology, however, is not central to the purpose of the present paper, so we will rather refer to the term selective imitation.

on the object's distinctive properties, while arbitrary actions can be performed on any object. When an adult clicks a metal object onto a magnet, for example, the child can discover a new and distinctive property – and thus the function – of the magnet, namely that it can hold other objects. In contrast, arbitrary actions neither require distinctive object properties, nor do they lead to a specific end state. For example, lifting an object and placing it back on the table is defined as an arbitrary action. Functional and arbitrary actions in this study were independent from each other and not constrained by an overall action goal.

In addition, functional vs. arbitrary target actions were systematically varied in the present study in two experiments testing deferred imitation in a group of 18-month-olds (Experiment 1) and in a group of 12-month-olds (Experiment 2). While in 18-month-olds two memory tests were administered, after a short (30 min) as well as a long (2 weeks) delay, the 12-month-olds were only tested after the short retention interval. First, we expected that both age groups would perform significantly more target actions after a demonstration than in a baseline phase, replicating the well-established memory effect. Second, deferred imitation rates were expected to be lower after the long retention interval than after the shorter retention interval, thus indicating forgetting. Third, we assumed that both age groups would imitate significantly more functional than arbitrary target actions (functionality effect), indicating selective deferred imitation. Fourth, in line with findings by Nielsen (2006) and the two-function theory by Uzgiris (1981), we expected a specific age pattern: while 18-month-olds were expected to imitate both kinds of target actions, the number of imitated arbitrary actions being smaller, 12-month-olds were expected to imitate only functional target actions. Fifth, we expected that arbitrary target actions would be forgotten to a larger amount than functional ones (selective forgetting).

2. Experiment 1

2.1. Method

2.1.1. Participants

$N = 31$ healthy, 18-month-old infants (16 girls) participated in this experiment. Their mean birth weight was $M = 3426$ g ($SD = 384.7$) and their APGAR-scores ranged from 9 to 10, with a mean of $M = 9.9$ ($SD = .2$) for the 10 min score. Their age at the first session ranged from 538 to 564 days, with a mean of $M = 552$ days ($SD = 7.5$). At the second session, their mean age was $M = 567$ days ($SD = 7.9$) indicating an age difference of $M = 15$ days ($SD = 2.3$). Nine further infants were tested but excluded from the final sample because of technical problems ($n = 1$), birth weight below 2500 g ($n = 2$), illness on the testing day ($n = 1$), clinically diagnosed eye or motor impairments ($n = 2$), or lack of cooperation ($n = 3$).

2.1.2. Procedure

Appointments were made for a time of the day when the caregivers reported the children to be alert and likely to engage in the procedure of the study. Prior to testing, the purpose and procedure of the study were explained to the caregiver and informed consent was obtained.[2] In addition, a short exploration of background information about pregnancy, children's postpartum health state and further life circumstances was conducted. Meanwhile, the child had the possibility to play and get familiar with the environment and the experimenter.

Testing took place in a sparsely furnished testing room where the child was seated on the caregiver's lap at a table, opposite to the experimenter. Caregivers were asked not to give any hints about what to do with the objects and not to name them.

2.1.2.1. Session 1. After approximately 2 min of warm-up play with an attractive toy, baseline testing was conducted. The experimenter took the first object from a hidden container, placed it on the table in front of the child and directed the child's attention to it, saying: "Look, [Name]! You can play with this." Then, the object was handed over to the infant. After 30 s the experimenter removed the object and placed the next one on the table, saying: "Look, [Name], now you can play with this one." The same procedure was repeated for all target objects. Subsequent to the baseline testing, the experimenter demonstrated the target actions three times, each within roughly 30 s. She actively communicated the demonstration of new information, saying "Look, [Name], I will show you something!. Look, I will show it again."

During the 30-min delay children and parents stayed in the waiting room. The child participated in no additional tasks and was free to play. When the 30 min were over, the child and the caregiver were again escorted to the testing room. After the same warm-up play as before in the baseline testing, the recall phase began. The experimenter subsequently placed the objects on the table, allowing the child to play with each of them for 30 s.

2.1.2.2. Session 2. A second testing took place roughly two weeks later. Following a short greeting and warm-up, the infant and caregiver were escorted to the testing room. After the same warm-up play as in Session 1, the target objects were handed to the child, each of them for 30 s.

[2] The project was in full accordance with APA ethical guidelines.

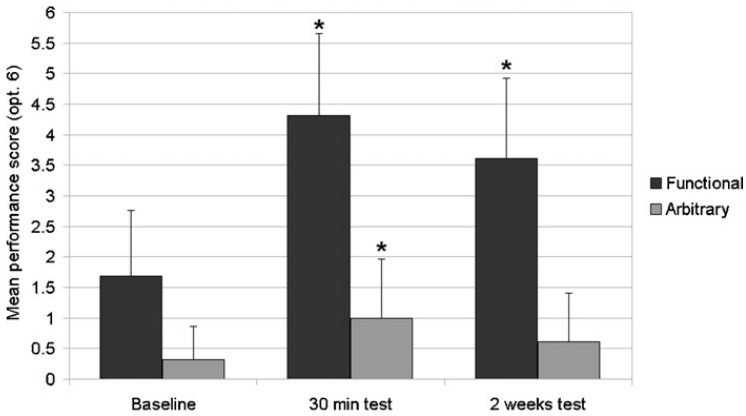

Fig. 1. Mean performance of functional vs. arbitrary target actions in the baseline and 30 min resp. two weeks after the demonstration in Experiment 1. Error bars indicate standard deviations and asterisks indicate significant differences (relative to baseline performance).

The child and the experimenter were videotaped in both sessions by two cameras, which were operated remotely from another room by a second experimenter.

2.1.3. Material and apparatus

The six target objects of the Frankfurt Imitation Test for 18 Month Old Children were used (FIT 18, see Goertz et al., 2008). Two target actions were presented with each object: a functional and an arbitrary one. The objects and the corresponding target actions are shown in Table 1.

To control for effects based on temporal order of action presentation, the presentation order of functional vs. arbitrary target actions was varied in an incomplete counterbalanced design. In the condition 'Presentation Order 1' ($n = 21$) the functional target actions were presented firstly for the second, the third and the sixth item, and the arbitrary target actions were presented thereafter. In the condition 'Presentation Order 2' ($n = 10$) the target actions were presented in the reversed order.

A naïve rater scored the performance of target actions in the videotaped sessions using operational definitions (see Table 1). One third of the videotapes was also scored by a second rater and a good inter-rater reliability was obtained, $\kappa = .90$ ($p < .001$). Rater disagreement was resolved in a forced consent session.

2.2. Results

The mean imitation rates of functional vs. arbitrary actions in the baseline, the 30 min test and the 2 weeks test are shown in Fig. 1.

A multivariate ANOVA was used to test whether the performance rates in the baseline, the 30 min test and the two weeks test differed between boys and girls, resp. between the two presentation order conditions. Neither gender, $F(3, 25) = 94$, *ns.*, nor presentation order, $F(3, 25) = 21$, *ns.*, had a main effect on the performance rates, and no interaction was found, $F(3, 25) = .69$, *ns.* Thus, these factors will not be considered in further analysis.

To test the memory and the functionality hypotheses, a two factor repeated measures ANOVA was conducted composing of the within-subjects factors experimental phase (baseline, 30 min test, 2 weeks test) and functionality (functional, arbitrary). Main effects of experimental phase, $F(2, 29) = 39.08$, $p < .05$ and of functionality, $F(1, 30) = 166.73$, $p < .05$, as well as an interaction, $F(2, 29) = 25.69$, $p < .05$, were found.

Additional paired-samples *t*-tests[3] showed that performance rates of target actions significantly differed between the baseline and the 30 min test, $t = -8.36$, $p < .006$, between the baseline and the 2 weeks test, $t = -7.18$, $p < .006$, and also between the 30 min test and the 2 weeks test, $t = 3.1$, $p < .006$. This shows that 18-month-olds performed significantly more target actions in both test phases than in the baseline, which is an indication of a memory effect. Furthermore, there was a significant difference between memory performance level in the 30 min test and in the 2 weeks test, indicating that the longer retention interval had a negative effect on infants' memory performance (forgetting).

The interaction between experimental phase and functionality suggests that the experimental phases influenced the memory performance of functional vs. arbitrary target actions in different ways. In the following, this interaction will be examined in more detail. Paired samples *t*-tests showed that memory performance of functional actions was significantly higher both in the 30 min test and in the 2 weeks test than in the baseline phase, $t = -9.31$, $p < .006$ and $t = -7.27$, $p < .006$, respectively. However, the difference between the 30 min test and the 2 weeks test was not significant, $t = 2.88$, *ns.* Performance rates of arbitrary actions differed between the baseline and the 30 min test, $t = -3.41$, $p < .006$, but did not differ

[3] Significance levels for *t*-tests in both Experiment 1 and Experiment 2 were Bonferroni adjusted.

Table 1
Objects and target actions with operational definitions used in Experiment 1. Arbitrary target actions are written in standard, functional target actions in bold and operational definitions in italics.

	Ship	Cow and metal box	Mouse	Frog and ring	Drum	Duck and octopus
						
Action 1	Taking the ship from one hand to another and back *Will be coded as yes, if the child takes the ship from one hand to the other*	**Clicking the box on the cow's belly** *Will be coded as yes, if the child clicks the box on the cow's belly, even if the magnets do not hold*	**Shutting the mouse (noise effect)** *Will be coded as yes, if the child clicks the mouse, even if it is too weak to produce a noise*	Sitting the frog into the ring and sliding it to and fro *Will be coded as yes, if the child slides the frog to and fro on the table, regardless if the frog is sitting in the ring*	Sliding the drumstick around the drum *Will be coded as yes, if the child slides the drumstick around or next to the drum*	**Sitting the duck on the octopus** *Will be coded as yes, if the child places the duck onto the octopus*
Action 2	**Putting a hand into the ship and waving** *Will be coded as yes, if the child puts a hand into the ship*	Lifting the cow from the table and placing it back *Will be coded as yes, if the child lifts the cow and places it back on the table, regardless if the metal box is on the belly*	Moving the mouse on a curvy path *Will be coded as yes, if the child pushes the mouse forwards on the table, regardless if the path is curvy*	**Putting a finger into the frog and holding it upright** *Will be coded as yes, if the child puts a finger into the frog*	**Pressing the red button (noise effect)** *Will be coded as yes, if the child presses the red button on the drum*	Turning the duck *Will be coded as yes, if the child turns the duck, regardless if it is sitting on the octopus*

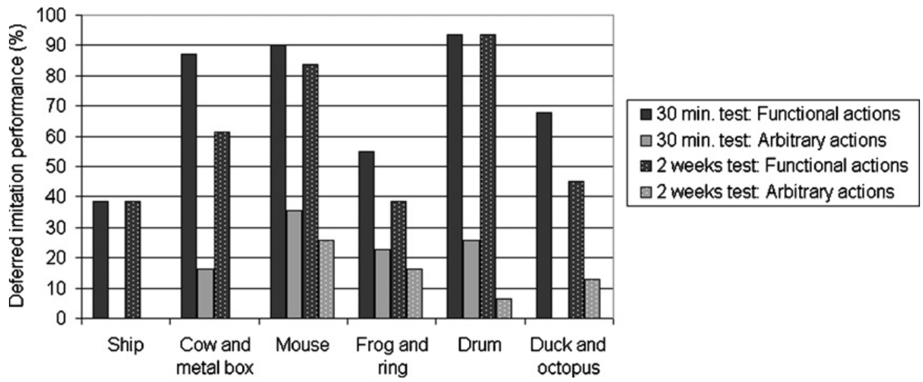

Fig. 2. Deferred imitation performance of the individual target actions in Experiment 1.

between the baseline and the 2 weeks test, $t = -2.19$, *ns.* The difference between the 30 min test and the 2 weeks test was not significant, either, $t = 1.93$, *ns.*

Deferred imitation performance for the different target actions in the 30 min test and in the 2 weeks test is presented in Fig. 2. An analysis on item level showed that with each object, the functional action was imitated more frequently than the arbitrary one. Therefore, the functionality effect was not only found on the overall imitation rate but also on item level. This holds true for both test phases.

3. Experiment 2

3.1. Method

3.1.1. Participants

$N = 31$ healthy, 12-month-old infants (17 girls) participated in Experiment 2. Their mean birth weight was $M = 3478$ g ($SD = 370.5$) and their APGAR-scores ranged from 7 to 10, with a mean of $M = 9.95$ ($SD = .22$) for the 10 min score. Their age ranged from 354 to 379 days, with a mean of $M = 368$ days ($SD = 7.3$). Two further infants were tested but not included in the final sample because of low birth weight (<2500 g).

3.1.2. Procedure

The procedure was identical to Session 1 of the first experiment. After a warm-up period, a baseline phase began, assessing spontaneous playing behavior. This was followed by a demonstration phase. After a delay of 30 min the recall phase began. The experimenter established the same communicative context as in Experiment 1.

Experiment 2 was administered by two female experimenters. Both of them tested about 50% of the children.

3.1.3. Material and apparatus

The material consisted of the five objects used in the Frankfurt Imitation Test for 12 Month Old Infants (FIT 12, see Goertz, Knopf, Kolling, Frahsek, & Kressley, 2006). Two actions were presented with each object: a functional and an arbitrary one. The objects and the corresponding target actions are presented in Table 2.

Presentation order of target actions was varied both across items and participants in an incomplete counterbalanced measurement design. In the condition ‘Presentation Order 1’ ($n = 21$) the second, the fourth and the fifth item started with the functional target action, and the other items with the arbitrary one. In the condition ‘Presentation Order 2’ ($n = 10$) the target actions were demonstrated in the reversed order. This design aimed at controlling for potential order effects for imitation.

All videotaped sessions were scored by a naïve rater who was blind according to the hypotheses of the study using operational definitions (see Table 2). One third of the videotapes were also scored by a second rater. The inter-rater reliability reached $\kappa = .84$ ($p < .001$) indicating a good reliability. In the following forced consent session rater disagreement was solved.

3.2. Results

Fig. 3 presents the mean imitation performances for functional vs. arbitrary target actions in the baseline and test phase.

A multivariate ANOVA neither found a main effect for gender, $F(2, 24) = .1$, *ns.*, nor for presentation order, $F(2, 24) = .34$, *ns.*, nor for experimenter, $F(2, 24) = 1.25$, *ns.*, and there were no significant interactions. So for further analysis, these factors will not be considered.

To test the memory and functionality hypotheses, a two-level repeated measures ANOVA across the within-subjects factors experimental phase (baseline, test) as well as functionality (functional, arbitrary) was conducted. A significant main effect of experimental phase was found, $F(1, 25) = 45.48$, $p < .05$, indicating that 12-month-olds performed more target actions

Table 2
Objects and target actions with operational definitions used in Experiment 2. Arbitrary target actions are written in standard, functional target actions in bold and operational definitions in italics.

	Tin can	Pig and hat	Bowl and stirrer	Mouse	Drum
					
Action 1	Blowing on the tin *Will be coded as yes, if the child blows or tries to blow on the tin can*	**Placing the hat on the pig's head** *Will be coded as yes, if the child places the hat somewhere on the pig*	Placing the bowl on the other side of the stirrer *Will be coded as yes, if the child lifts the bowl and places it on the other side of the stirrer or lifts the stirrer and places it on the other side of the bowl*	**Shutting the mouse (noise effect)** *Will be coded as yes, if the child clicks the mouse, even if it is too weak to produce a noise*	Sliding the drumstick around the drum *Will be coded as yes, if the child slides the drumstick around or next to the drum*
Action 2	**Shaking the tin up and down (noise effect)** *Will be coded as yes, if the child shakes the tin can at least twice up and down or in any other direction*	Lifting the pig and placing it back on the table ("jumping") *Will be coded as yes, if the child lifts the pig and places it back on the table, regardless if the hat is on the pig or not*	**Turning the bowl and stirring in it** *Will be coded as yes, if the child turns the bowl around and puts one end of the stirrer in it*	Moving the mouse on a curvy path *Will be coded as yes, if the child pushes the mouse forwards on the table, regardless if the path is curvy*	**Pressing the red button (noise effect)** *Will be coded as yes, if the child presses the red button on the drum*

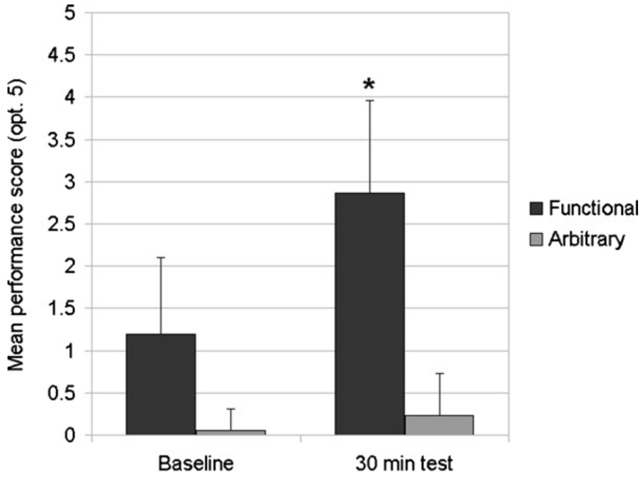

Fig. 3. Mean performance of functional vs. arbitrary target actions in the baseline and 30 min after the demonstration in Experiment 2. Error bars indicate standard deviations and asterisks indicate significant differences (relative to baseline performance).

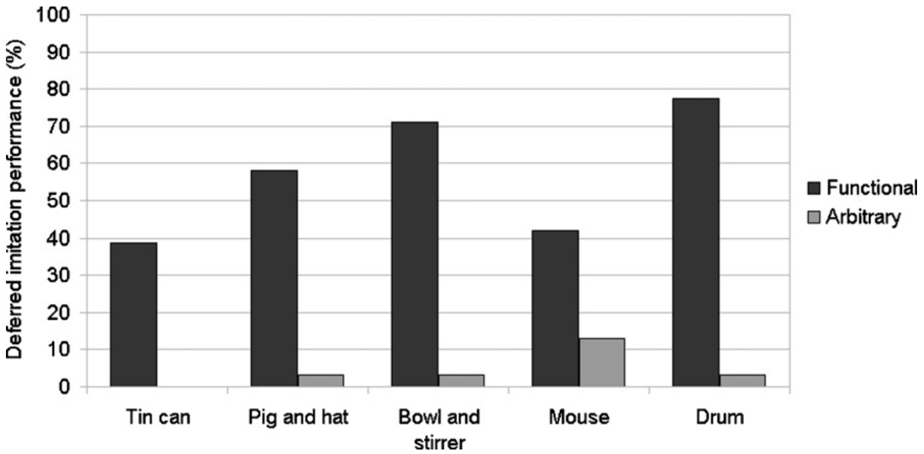

Fig. 4. Deferred imitation performance of the individual target actions in Experiment 2.

in the test than in the baseline phase. The factor functionality also had a main effect on imitation rates, $F(1, 25) = 203.77$, $p < .05$, showing that significantly more functional than arbitrary target actions were imitated. The interaction of the two factors was also significant, $F(1, 25) = 47.27$, $p < .05$, which shows that the performance of functional vs. arbitrary actions was influenced by the experimental phases differently. Paired samples *t*-tests revealed that the performance rate of functional actions was significantly higher in the test than in the baseline phase, $t = -7.65$, $p < .025$. The performance rate of arbitrary actions, on the contrary, did not differ between the two phases, $t = -1.54$, *ns*. Thus, the memory effect relied on a specific enhancement of functional actions in the test phase.

Deferred imitation performance for each target action is presented in Fig. 4. An item-specific analysis revealed that with each object, 12-month-olds imitated the functional action more frequently than the arbitrary one.

As imitation rates for arbitrary target actions in this age group were low, no second memory test after a longer retention interval was conducted.

4. Discussion

The present study varied functional and arbitrary target actions in two experiments with 12- and 18-month-old infants. As predicted, a memory effect was found in both 12- and 18-months-olds, showing that infants can acquire new object-related actions by imitating the behavior of a human model. This finding replicates a series of former studies (e.g., Barr et al., 1996; Kolling et al., 2010; Meltzoff, 1995). Most interestingly, however, the imitation rate was moderated by target action functionality: Both 12- and 18-month-olds imitated significantly more functional than arbitrary target actions. This functionality effect was not only observed in the overall imitation performance but also holds true for each specific item. This finding is in line with the idea that infants do not blindly copy what is shown by a model but imitate selectively. While different determinants of infants' selective imitation have been studied in prior research (e.g., goal-relatedness of a target action), the current study additionally shows that selective imitation occurs as a function of action functionality. In contrast to previous selective imitation studies that varied the relevance of action steps in relation to an overall action goal, however, the target actions of the present study were independent from each other as well as from overall action goals. The only relation between each pair of functional vs. arbitrary action was that they were performed on the same object. They were neither subordinate to a common action goal, nor were they causally constrained. In line with this idea, counterbalancing the order of the target actions had no effect on infants' imitation performance, demonstrating that infants recognize functional actions separately without relying on relations of a multi-step action sequence. In terms of experimental variations it is also important to note that the present study held factors constant which were found to influence infants' imitation in previous studies, i.e., intentionality cues (e.g., Carpenter et al., 1998) or social communication (e.g., Király, 2009; Nielsen, 2006). The only factor that could have had an impact on the selection of target actions to be imitated was functionality.

In addition, differences between the two age groups were observed with respect to imitation preferences. While 18-month-olds imitated both functional and, to a lesser degree, arbitrary actions (compared to baseline behavior), 12-month-olds imitated functional actions and almost completely ignored arbitrary ones. This finding is in line with observations obtained from prior research on selective imitation (e.g., Carpenter et al., 2005). With increasing age, the communicative function in the imitation process may become more important, thus leading to more comprehensive imitation of target actions. This consideration has to be studied in further research.

With respect to action retention over a long retention interval, the results of Experiment 1 showed that the deferred imitation rate was higher after the short (30 min) than after the long (2 weeks) delay, indicating the forgetting of target actions. A further assumption of our research was that infants would imitate both types of actions (with a higher amount of functional than arbitrary actions) after the 30 min delay but retain only the functional ones after the 2 weeks delay. In other words, we expected that infants would selectively forget arbitrary target actions to reduce unnecessary memory storage space. Our findings, however, did not confirm this hypothesis. The forgetting rates between the 30 min and 2 weeks delay were parallel for functional and arbitrary actions. In other words, the absence of a memory effect for arbitrary actions after the 2 weeks delay was not, as expected, related to faster forgetting, but to the low imitation rate after 30 min.

Taken together, these findings demonstrate that both age groups acquire new actions by observing a model. While the age groups differ with respect to the amount of actions acquired, in that older infants reproduce more target actions, both age groups show a tendency to imitate functional target actions more often than arbitrary ones. This tendency to concentrate on functional target actions in imitation is stronger in younger infants than in older ones. While selective imitation was found in a first imitation test, assessed 30 min after target action demonstration, no further selection occurred during retention of the actions for longer intervals (2 weeks), since the forgetting rate was the same irrespective of the type of target action. These findings demonstrate that infants are tuned to imitate and learn important, relevant actions, i.e., functional object use from human models, although under certain circumstances they are capable of also retaining and imitating arbitrary ones. While infants learn how to use novel objects by imitating functional actions, the imitation of arbitrary actions observed in older infants may serve social functions.

Interpreted from a memory perspective, these findings strongly indicate that deferred imitation performance is not only constrained by memory capacity, but relies heavily on target action functionality. Selective imitation processes, thus, significantly influence memory processes. The more functional target actions are shown to an infant, the higher the (potential) imitation rate.

It still stands to reason, however, whether selective imitation processes happen during encoding, during storage or during retrieval of target actions. Besides the possibility that selective imitation affects encoding, storage or retrieval, more basic characteristics of information processing might also account for lower imitation rate of arbitrary actions. One might argue that infants attend much less to arbitrary than to functional target actions during action presentation. Future studies need to address these issues.

An applied conclusion of this finding is that a thorough, balanced construction of test items for deferred imitation tests is important. As reliable and valid testing of memory performance should be a central goal of memory assessment in infancy, the distinction of functional and arbitrary target actions should be taken into account more thoroughly.

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Paper 2

Kolling, T., Óturai, G., & Knopf, M. (in press). Is selective attention the basis for selective imitation in infants? An eye-tracking study of deferred imitation with 12-month-olds. *Journal of Experimental Child Psychology.*

---------- Továbított levél ----------

From: "David Bjorklund" <dbjorklu@fau.edu>

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Date: 24 Jan 2014 15:00:15 +0000

Subject: Your Submission

Ms. Ref. No.: JECP-D-12-00441R3

Title: Is selective attention the basis for selective imitation in infants? An eye-tracking study of deferred imitation with 12 month-olds

Journal of Experimental Child Psychology

Dear Dr. Thorsten Kolling,

I have carefully read the revision of your manuscript and believe you have been responsive to the earlier set of comments. I am therefore pleased to inform you that your paper "Is selective attention the basis for selective imitation in infants? An eye-tracking study of deferred imitation with 12 month-olds" has been accepted for publication in Journal of Experimental Child Psychology.

When your paper is published on ScienceDirect, you want to make sure it gets the attention it deserves. To help you get your message across, Elsevier has developed a new, free service called AudioSlides: brief, webcast-style presentations that are shown (publicly available) next to your published article. This format gives you the opportunity to explain your research in your own words and attract interest. You will receive an invitation email to create an AudioSlides presentation shortly. For more information and examples, please visit http://www.elsevier.com/audioslides

Congratulations on an excellent piece of research. I look forward to seeing the article in print and I hope you will continue to consider JECP as an outlet for your work.

Yours sincerely,

David F. Bjorklund, Ph.D.

Editor

Journal of Experimental Child Psychology

Is selective attention the basis for selective imitation in infants?

An eye-tracking study of deferred imitation with 12 month-olds

Word count: 8100

Abstract

Infants and children do not blindly copy every action they observe during imitation tasks. Research demonstrated that infants are efficient selective imitators. The impact of selective perceptual processes (selective attention) for selective deferred imitation, however, is still poorly described. The present study therefore analyzed 12-month-old infants' looking behavior during demonstration of two types of target actions, arbitrary vs. functional actions. A fully automated remote eye-tracker was used to assess infants' looking behavior during action demonstration. After a 30-minute-delay, infants' deferred imitation performance was assessed. Next to replicating a memory effect, results demonstrate that infants do imitate significantly more functional than arbitrary actions (functionality effect). Eye-tracking data show that whereas infants do not fixate significantly longer on functional than on arbitrary actions, amount of fixations and amount of saccades differ between functional and arbitrary actions indicating different encoding mechanisms. Additionally, item-level findings differ from overall findings indicating that perceptual and conceptual item features influence looking behavior. Looking behavior on both overall and item-level, however, does not relate to deferred imitation performance. Taken together, the findings demonstrate that, on the one hand, selective imitation is not explainable merely by selective attention processes. On the other hand, notwithstanding this reasoning, attention processes on item-level are important for encoding processes during target action demonstration. Limitations and future studies will be discussed.

Keywords: Selective Imitation, Infancy, Deferred Imitation, Eye-Tracking, Arbitrary vs. Functional Actions

Understanding and reproducing other persons' actions, i.e. imitating, is crucially relevant for learning new behaviors throughout the whole lifespan. Imitative learning requires that an agent properly observes specific actions performed by a (human) model, encodes and represents these actions and finally maps these actions onto his or her own motor repertoire. One of the major problems for an imitative learner is to extract relevant aspects out of a perceptual stream of a series of activities constituting an action of an agent. Imagine, for example, somebody learning to play the trumpet by not only taking music classes but also watching movies of his/her favorite trumpet player Miles Davis. Each time Miles Davis makes bending postural motions while playing his tunes, the learner needs to evaluate and select which actions were related to playing the instrument or just to stage performance.

Infants and children learning via imitation face comparable and even more complicated problems during action processing and action understanding. In a naturalistic, non infant-directed observation and imitation setting and even in a more restricted, infant-directed educational situation, a caregiver often produces a significant amount of arbitrary amongst functionally relevant actions. An imitative learning laboratory setting allows researchers to manipulate the specific character of the actions demonstrated to the infants by, for example, showing a number of arbitrary actions in line with functional actions.

Since the seminal experimental studies by Meltzoff (1985, 1988) relying on earlier work by Piaget (1999/1951) infants' imitation behavior is used to study learning and memory. In a typical imitation paradigm, infants or children observe a set of actions demonstrated by an experimenter during a demonstration phase and then they are allowed to play freely with the objects during an imitation phase. Whereas in an immediate imitation paradigm infants are immediately allowed to play with the objects, in deferred imitation studies there is a delay of minutes, hours or even days between demonstration and imitation phase (e.g., Barr, Dowden, & Hayne, 1996). Depending on the design of the study, either a baseline phase prior to the demonstration phase (elicited imitation design; e.g. Bauer, 1996, 2005) or a control group (observation-only design, e.g., Barr et al., 1996; Meltzoff, 1985, 1988) allows controlling and evaluating for spontaneous production of target actions.

The immediate imitation paradigm is mostly used within a social cognition oriented research approach to study how infants process others' actions. This approach focuses on describing how infants process, interpret and imitate actions and how they additionally interpret the demonstration situation. For example, in a well-known study, Gergely, Bekkering and Király (2002) demonstrated that 14-month-old infants imitated a head-touch action (Meltzoff, 1988), i.e., they switched on a lamp via touching it with the head, only when the model's hands were free during target action demonstration. In case the model's hands were occupied, infants switched the lamp on with their hands, showing that infants are selective imitators. This finding was interpreted in the sense that early imitation of goal-directed actions is a selective, inferential process by which imitators evaluate the rationality of the means in relation to the constraints of the situation (Csibra & Gergely, 2007; Gergely & Csibra, 2003). In line with this idea, a series of studies demonstrated that selective imitation is influenced by several experimental factors, e.g., communicative cues (Nielsen, 2006) and the demonstration situation (Király, 2009). This higher cognitive, interpretative explanation of selective imitation is, however, heavily debated in the imitation literature. A different research account conceptualizes (selective) imitation as a rather biologically driven, relatively automatic process of perception-action matching (e.g., Hauf & Prinz, 2005; Meltzoff, 2007; Paulus, Hunnius, Vissers, & Bekkering, 2011a). As an extension of their idea, Paulus, Hunnius, Vissers, and Bekkering (2011b) argue for a two-stage model of infants' imitative learning. In a first stage, observing another person's action activates a corresponding motor code. In a second stage, observed action effects (see Elsner, 2007, for a review) trigger the activation of a perceptual and motor code coupling leading to imitation.

In contrast to the social cognition oriented research approach, the deferred imitation paradigm is used within a memory oriented research approach to study memory performance in infants, toddlers and children. Research within this approach focuses on describing how memory capacities develop from infancy to childhood. Experimental and longitudinal findings demonstrated that with increasing age, infants are able to retain a higher number of information units, i.e., target actions within a deferred imitation task, over extended periods of time (see Rovee-Collier & Barr, 2010, for a comprehensive review).

By bringing together ideas from the social cognition oriented and the memory-oriented research approach, Óturai, Kolling, Rubio Hall, and Knopf (2012) recently studied selective imitation within a deferred imitation setting. The authors varied target action functionality using items of a standardized deferred imitation test (Kolling, Goertz, Frahsek, & Knopf, 2010). Results demonstrated that 12- and 18-month-old infants imitated significantly more functional than arbitrary target actions, thereby indicating selective imitation. Specifically, 12-month-old infants imitated almost exclusively functional target actions (e.g., closing a toy mouse while producing a sound effect) after a short delay (30 minutes). After the short delay, 18-month-old infants imitated some arbitrary target actions (e.g., moving the mouse without an obvious goal) but significantly more functional ones. When retested after a 2-week-delay, infants' memory performance for both functional and arbitrary target actions decreased linearly and parallel, indicating that rather short-term declarative memory processes cause these functionality effects.

Taken together, findings from both social cognition oriented and memory oriented imitation research approaches show that infants and children do not blindly copy actions they perceive. In theory, however, the basis of selective imitation is heavily debated. From a memory process perspective, for example, it is far from being clear how infants encode, store, and retrieve arbitrary and functional actions. Nevertheless, almost all theoretical accounts on selective imitation propose that the selection of target actions takes place at a later stage than mere perception (for an exception, see Beisert, Zmyj, Liepelt, Jung, Prinz, & Daum, 2012). The possibility that infants might not attend to all kinds of target actions equally has been speculated about (cf. Carpenter, Akhtar & Tomasello, 1998), but it has not been systematically investigated yet.

The current study therefore analyzes perceptual processes using an eye-tracker within a deferred imitation task. Although eye-tracking has become a powerful research method in the last couple of years and has been applied in a wide range of developmental studies (see Gredebäck, Johnson, & van Hofsten, 2010; Karatekin, 2007, for overviews), within deferred imitation research, to our knowledge, no study to date used an eye-tracking approach. However, a study with autistic children, for example, used an eye-tracking approach with looking behavior analyses during an imitation demonstration (Vivanti, Nadig, Ozonoff, & Rogers, 2008). Being empirically inspired by Vivanti et al.'s (2008) study, we recorded fine-grained (frame-by-frame) eye movements of 12-month-old infants in a typical, dynamical imitation setting with an eye-tracker using different areas of interest (AOI). We thereby defined functional actions against the background of a multi-component theory of object function (Chaigneau, Barsalou, & Sloman, 2004) as being derived from the objects' physical properties and affordances (Gibson, 1979) or of their conventional use (e.g., using a stirrer to stir in a bowl). In contrast, arbitrary actions can be performed on any object of manipulative sizes (e.g., to lift the bowl and to place it on the other side of the stirrer). In line with the study by Óturai et al. (2012), items were derived from a standardized deferred imitation test (Frankfurt Imitation Test for 12-Month-Old Infants, Kolling et al., 2010). Some functional actions thereby lead to a sound effect, others lead to a visible end state, and some others presented the object's conventional function. When an adult clicks a metal object onto a magnet, for example, the child can discover a new and specific property – and thus the function – of the magnet, namely that it can hold other objects. In contrast, arbitrary actions neither require specific object properties nor do they lead to a specific end state. For example, lifting an object and placing it back on the table is defined as an arbitrary action. Functional and arbitrary actions in this study were independent from each other and not constrained by an overall action goal.

We assumed that infants will perform more target actions in the deferred imitation than in the baseline phase replicating the well-established *memory effect* (e.g., Barr et al., 1996). In line with findings by Óturai et al. (2012) we hypothesized that infants will imitate significantly more functional than arbitrary target actions in the deferred imitation phase (*functionality effect*). Given the assumption that selective imitation might rely on early perceptual processes, we hypothesized that infants will look more towards functional than towards arbitrary actions (*selective attention hypothesis*).

Method

Participants

$N = 41$ infants[1] (22 girls) were tested in this study. Criteria for inclusion in the study were normal birth weight (2500-4500 g), 37 or more weeks of gestation and an APGAR-score (5 minutes) of 7 or above, as well as completion of all experimental phases (baseline testing, eye-tracking, imitation phase). Two infants were tested but excluded from the sample because of low birth weight (< 2500 g). Ten infants were excluded because of errors during the eye-tracking procedure (poor calibration/validation) mostly resulting from infants' fussiness. Six further infants were excluded because they refused to play with more than one out of five objects either in the baseline or in the test phase. Thus, the final sample included $N = 23$ infants (14 girls), with a mean birth weight of $M = 3478$ g ($SD = 465$), a mean APGAR score of $M = 9.9$ ($SD = .29$) and mean gestation of 39.6 weeks ($SD = .99$). Infants' age ranged from 353 to 378 days ($M = 369$, $SD = 7.6$ days).

Materials

[1] The present study has been conducted in accordance with the ethical guidelines of the German Psychological Society and is also in line with the Ethical Principles of Psychologists and Code of Conduct of the American Psychological Association.

Target actions and objects. The testing material was adapted from the Frankfurt Imitation Test for 12 Month Old Infants (FIT 12; see Kolling et al., 2010; Óturai et al., 2012). Five objects were used and two action types, i.e. functional and arbitrary actions, were demonstrated with each of them. For example, the functional use of the bowl and stirrer was to stir in the bowl with the stirrer. The arbitrary action was to lift the bowl and to place it on the other side of the stirrer that was lying on the table. Objects and corresponding arbitrary and functional target actions are presented in Table 1.

Table 1

Objects and target actions with operational definitions

Item	Objects	Functional action	Arbitrary action
Tin can		Shaking the tin up and down *Will be coded as yes, if the child shakes the tin at least twice up and down or in any other direction*	Blowing on the tin *Will be coded as yes, if the child blows or tries to blow on the tin*
Pig and hat		Placing the hat on the pig's head *Will be coded as yes, if the child places the hat somewhere on the pig*	Lifting the pig and placing it back on the table ("jumping") *Will be coded as yes, if the child lifts the pig and places it back on the table, regardless if the hat is on the pig*
Bowl and stirrer		Turning the bowl and stirring in it *Will be coded as yes, if the child turns the bowl around and puts one end of the stirrer in it*	Placing the bowl on the other side of the stirrer *Will be coded as yes, if the child lifts the bowl and places it on the other side of the stirrer or lifts the stirrer and places it on the other side of the bowl*
Mouse		Shutting the mouse four times *Will be coded as yes, if the child shuts the mouse, even if it is too weak to produce a sound*	Sliding the mouse on a curvy path *Will be coded as yes, if the child pushes the mouse forward on the table*
Drum		Pressing the red button *Will be coded as yes, if the child presses the red button on the drum*	Sliding the drumstick around the drum *Will be coded as yes, if the child slides the drumstick around or next to the drum*

Note. Operational definitions are printed in italics. The items "Pig and hat" and "Mouse" started with the functional action followed by the arbitrary action, and the items "Tin can", "Bowl and stirrer" as well as "Drum" started with the arbitrary action followed by the functional action.

Target actions were presented to infants in a fixed order with a fixed position variation of arbitrary and functional actions, i.e., the first item started with an arbitrary action, the second with a functional action and so on.

Inter-rater reliability. Videotaped target action completion was scored by a naïve rater who was blind to the hypotheses of the study. One third of the videotapes were randomly selected and additionally scored by a second naïve rater. The inter-rater reliability reached κ = .87 ($p < .001$). Both raters used the operational definitions listed in Table 1. Rater disagreement was resolved by forced consent.

Action demonstration video. The demonstration video depicted the experimenter, who was present during the whole testing procedure, sitting at the table in the testing room frontally facing the infant. The video started with an intro sequence showing the experimenter sitting at the table and saying "You played very nice, and now I am going to show you what else you can do with those things". Then, the video showed the experimenter performing the target actions. All target actions were demonstrated four times, each within 30 seconds. Before the demonstration of each item, the experimenter actively communicated by saying "Look, I will show you something! ... Look, I will show it again" in between the target action demonstration.

Eye-tracking system. An EyeLink Remote 1000 ® (SR Research Ltd.) was used to record infants' eye movements during target actions observation. The infrared eye-tracking camera was fixed beneath the presentation screen. A flexible hydraulic arm allowed easy adaptation of eye-tracking camera and presentation screen to each individual infant. Presentation of the action demonstration video and eye movement recording were controlled by an experimenter via two personal computers in an adjacent control room. A host PC was used for controlling the eye-tracking camera, i.e., to perform camera setup, calibration and validation prior to running the experiment. A display PC (connected via Ethernet-cable) ran the experiment and collected eye movement data. The EyeLink Remote 1000 ® performs real-time eye-tracking at a sampling rate of 500 Hz with no loss of spatial resolution, computing true gaze position on the display viewed by the subject and detecting eye-motion events such as saccades and fixations. Its average accuracy is 0.5° and it allows head movements of 22×18×20 cm (horizontal×vertical×depth) without accuracy reduction. The eye-tracker quickly recovers (*M* < 3.0 ms, *SD* = 1.11 ms) after a lost track. The action demonstration video was presented on a 17” LCD-screen using a resolution of 704×576 pixels, which corresponds with a width of 31.64 visual angles and a height of 25.36 visual angles.

Procedure

General test setting and background information. Appointments were scheduled during a time of the day when the caregivers reported the infant to be alert and likely to engage in the procedure of the study. Prior to testing, the purpose and procedure of the study were explained to the caregiver and informed consent was obtained. In addition, caregivers reported on background information about pregnancy, infant’s postpartum health state and additional life circumstances. Meanwhile, the infant had the possibility to play and get familiar with the environment and the experimenter.

Baseline target action performance testing. Testing took place in a sparsely furnished testing room (behavioral testing lab) where the infant was seated on the caregiver’s lap at a table, opposite to the experimenter. Caregivers were asked to refrain from giving hints about the functionality and/or names of the objects. After approximately two minutes of warm-up play with an attractive toy, baseline testing was conducted. The experimenter took the first object from a hidden container, placed it on the table in front of the infant and directed the infant’s attention to it by saying: “Look, [name]! You can play with this.” After 30 seconds the experimenter removed the object and placed the next one on the table, saying: “Look, [name], now you can play with this one.” The same procedure was repeated for all target objects. The infant’s spontaneous playing behavior was videotaped by two cameras, which were operated remotely from another room by a second experimenter.

Demonstration of target actions and infants’ eye-tracking. Subsequent to baseline testing, the behavioral testing lab was left. Infants and caregivers were then escorted to the eye-tracking lab. In the eye-tracking lab, target action demonstration and simultaneous eye-tracking were performed.

Before starting the eye-tracking test procedure, a small eye-tracking reference point sticker was attached to the infants' forehead. Then, the infant was seated on the caregiver's lap in front of the eye tracker screen. Infants' distance from the eye-tracker (optimal distance about 600 mm), as well as pupil and corneal reflection thresholds were adjusted. During both hardware and software set up, infants' attention was constantly directed to the screen by two moving cartoon snails.

Immediately following set-up, calibration and validation started. A five-point calibration was used with subsequently presented images of looming concentric white circles on a black background with a centered red dot at the following pixel locations: 359.5/287.5, 359.5/526.1, 359.5/48.9, 675.9/287.5, 43.1/287.5. The maximum size of the circles was 80 × 80 pixels. Calibration was performed using manual calibration mode to increase calibration and validation accuracy. Fixation to a calibration target was judged as correct, if (1) both pupil and corneal reflection were visible, (2) the crosshairs indicating the subject's gaze was stable, and (3) the spatial pattern of recorded gaze locations corresponded with the pattern of calibration targets being presented. After successful calibration, manual validation using the same set of images started. If calibration and/or validation failed, the exact same procedure was repeated until calibration and validation were acceptable or the procedure had to be aborted. As soon as acceptable calibration and validation was obtained (mean error in visual angles was $M = .71$, $SD = .28$), the action demonstration video was presented and participants' eye movements were recorded. After the action demonstration video was finished, the infant and their caregiver(s) were escorted to the waiting room.

Delay and imitation phase. During the 30-minute delay, the infant and caregiver(s) stayed in the waiting room. The infant participated in no additional tasks and was free to play. After the delay, the infant and the caregiver were again escorted to the behavioral testing lab.

After warm-up, the imitation phase began. The experimenter placed the objects subsequently on the table, encouraging the infant to play with each of them for 30 seconds. Infant's playing behavior was videotaped.

Data Analysis

Baseline behavior and deferred imitation performance. Baseline behavior and deferred imitation performance were calculated by summing up successful target action performance (according to operational definitions) for both arbitrary and functional target actions. The sum scores during baseline and deferred imitation phase, i.e. target action performance scores, were used as dependent variables in the deferred imitation task.

Saccade and fixation computation. For each data sample, the eye tracking software computed instantaneous velocity and acceleration and compared these to velocity and acceleration thresholds. If either was above threshold (saccade velocity threshold: 30 deg/s; saccade acceleration threshold: 8000 deg/s), a saccade signal was generated. If gaze was on the screen (i.e., subject not blinking or looking away) and no saccade signal was generated, the eye-tracker recorded a fixation towards the current gaze location.

Analysis of eye tracking data. Eye tracking data was obtained from fixation reports produced by the Eye Link® Data Viewer software.

Periods of Interest and Areas of Interest. The action demonstration video was divided into Periods of Interest (POIs) to enable the analysis of infants' gaze during different scenes. POIs were defined for the parts of the video that showed the model talking to the infant before demonstrating each pair of target action (*Talking POIs*), as well as for the parts showing the model demonstrating the functional and arbitrary target actions (*Functional Target Action POIs* and *Arbitrary Target Action POIs*).

As the experimenter performed natural movements with the objects in the action demonstration video, the position of Areas of Interest (AOIs) changed on a frame-to-frame basis. To account for that data and stimulus structure, the action demonstration video (containing a total 4092 frames corresponding to a total length of 161 seconds) was converted frame-by-frame into single .jpg-files using the software Free Studio (DVD Video Soft). Next, pixel coordinates of object/action and face area were measured using the image editing software Gimp. Then, pixel coordinates of both the experimenter's face area (*Face AOI*) and the object/action area (the object in the Talking POIs and the object with the experimenter's acting hand in the Target Action POIs, *Action AOI*) were obtained. Both Face and Action AOIs were defined separately for each object and each POI, taking the extreme positions of face or action, respectively, as the borders of the AOIs. AOIs of the item "pig and hat" in the Target Action POIs are exemplarily shown in Figure 1. POIs durations and AOIs sizes are listed in the Appendix.

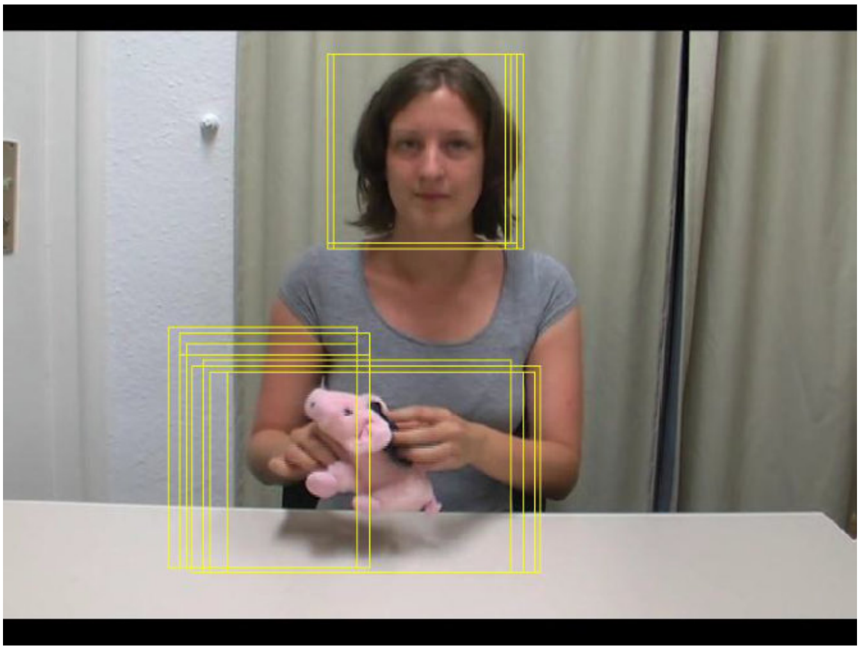

Figure 1. Face AOIs and Action AOIs during Target Action POIs of the item "pig and hat".

Eye tracking variables. The following variables were computed for each item and each POI: fixation time to the Face AOI and to the Action AOI, amount of fixations to the Face AOI and in the Action AOI, and amount of saccades within and between different screen areas (between the two AOIs, between each AOI and the rest of the screen, as well as within each AOI). To compensate for differences in POI duration, we calculated all variables as the percentage of total POI length. Additionally, to compensate for differences in AOI sizes, these percentage values of fixation times and amounts of fixations (but not of amounts of saccades) were divided by the relative size of the corresponding AOI (size of AOI divided by screen size). All statistical analyses were based on these corrected values. For the sake of simplicity, however, the term fixation time will be used to refer to corrected fixation times throughout the manuscript (this also applies for amounts of fixations and amounts of saccades).

Statistical analysis outline. First, we conducted a RM-ANOVA (with post-hoc calculations) with the within-subjects factors phase (baseline, test) and functionality (functional, arbitrary) using target action performance scores as dependent variable. Additionally, one-sample t tests tested whether the amount of newly acquired functional and arbitrary target actions, i.e., target actions that were performed in the imitation phase but not in the baseline phase, was significantly different from zero. Second, after analyzing on-screen fixations, we analyzed eye-tracking data (fixation times and amounts of fixations, amounts of saccades) with RM-ANOVAs (with post-hoc calculations) with the within-subjects factors AOI (Face, Action) and POI (Talking, Functional Target Action, and Arbitrary Target Action). Subsequently, we report on item-level effects. Last but not least, we calculated chi-square analyses (median split) and biserial correlations between fixation times, amounts of fixation, saccades, and deferred imitation performance.

Results

Baseline Behavior and Deferred Imitation of Target Actions

Preliminary analyses showed that seven out of twenty-three infants from the final sample refused to play with one out of five test objects in the test phase (bowl: 1 infant; mouse: 2 infants; pig: 4 infants). In the baseline phase, all infants in the final sample played with all objects. As gender had no effect on target action performance scores of both functional and arbitrary target actions in any of the experimental phases (all *ps* > .05), data were collapsed across gender.

Figure 2 depicts the target action performance scores of functional vs. arbitrary target actions in both baseline and test phase.

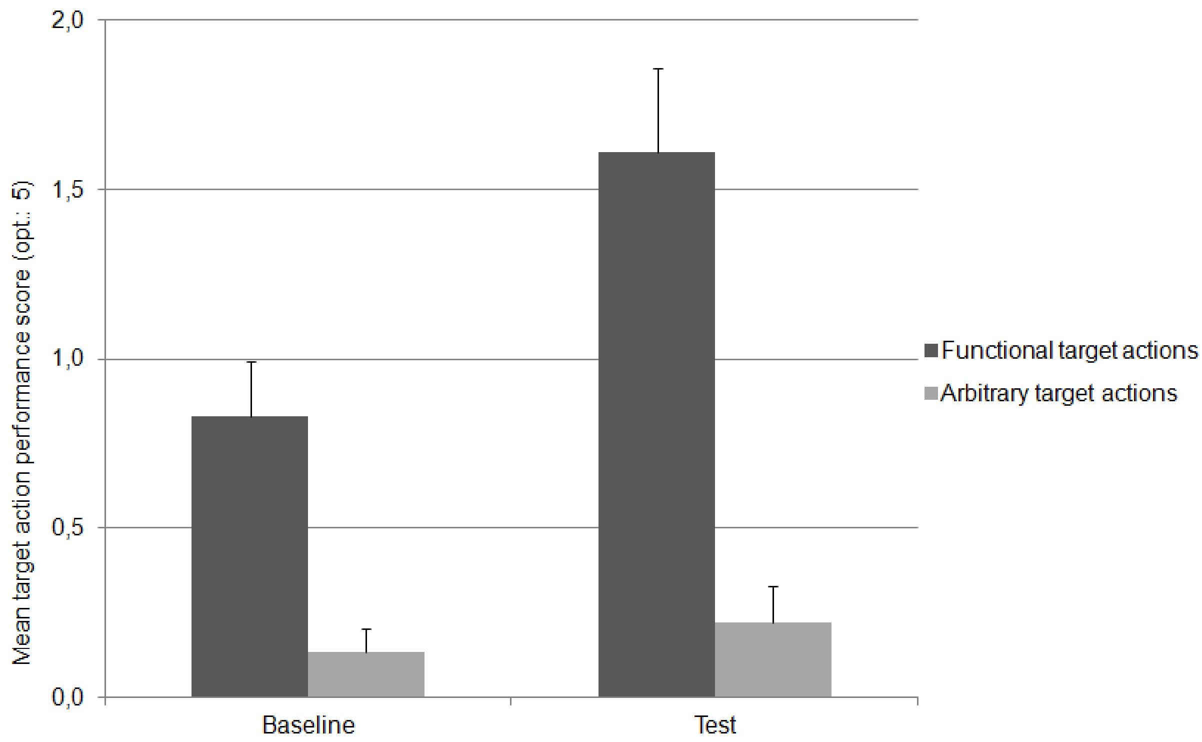

Figure 2. Mean performance scores of functional vs. arbitrary target actions in baseline and test phase. Error bars indicate standard errors.

A RM-ANOVA with the within-subjects factors experimental phase (baseline, test) and functionality (functional, arbitrary) showed a main effect of experimental phase, $F(1, 22) = 11.1$, $p = .003$, $\eta_p^2 = .33$, indicating that infants performed significantly more target actions in the test than in the baseline phase. The main effect of functionality was also significant, $F(1, 22) = 32.5$, $p < .001$, $\eta_p^2 = .60$, indicating that infants performed significantly more functional than arbitrary actions. The significant experimental phase × functionality interaction, $F(1, 22) = 5.9$, $p = .023$, $\eta_p^2 = .21$, revealed that the experimental phase affected target action performance scores of functional vs. arbitrary actions differently. Post-hoc comparisons (paired-sample t tests) showed that infants performed more functional target actions in the test than in the baseline phase, $t(22) = -3.33$, $p = .003$, $d = .77$, $r = .36$. In contrast, performance scores of arbitrary target actions did not differ between baseline and test phase, $t(22) = -.62$, $p = .539$, $d = .20$, $r = .10$. As infants already performed some functional target actions in the baseline phase, the amount of newly acquired target actions, i.e., target actions that were performed in the imitation phase but not in the baseline phase, was analyzed by one-sample t tests. These tests confirmed that the amount of newly acquired functional target actions was significantly larger than zero, $t(22) = 4.39$, $p < .001$, $d = 1.29$, $r = .54$. In contrast, the amount of newly acquired arbitrary target actions did not significantly differ from zero, $t(22) = 2.01$, $p = .057$, $d = .60$, $r = .29$.

Looking Behavior During the Demonstration Phase

As preliminary analyses showed that participants' gender did not have an effect on any of the gaze variables (all *p*s > .05), i.e., fixation times, amounts of fixations and amounts of saccades, data were collapsed across gender. In the following, both fixation times and amounts of fixations to different AOIs during different POIs are reported. Additionally, different saccade types are analyzed.

On-screen fixation times. Infants spent about ¾ of the time during target action demonstration (Target Action POIs) fixating the screen. Mean on-screen fixation times did not differ between Functional ($M = 75.26\%$, $SD = 17.63$) and Arbitrary Target Action POIs ($M = 72.87\ \%$, $SD = 19.74$), $t(22) = 1.85$, $p = .078$.

Fixation times to different AOIs during different POIs. Infants' mean fixation times to the Face AOI and to the Action AOI during Talking POIs, Functional Target Action POIs and Arbitrary Target Action POIs are shown in Figure 3.

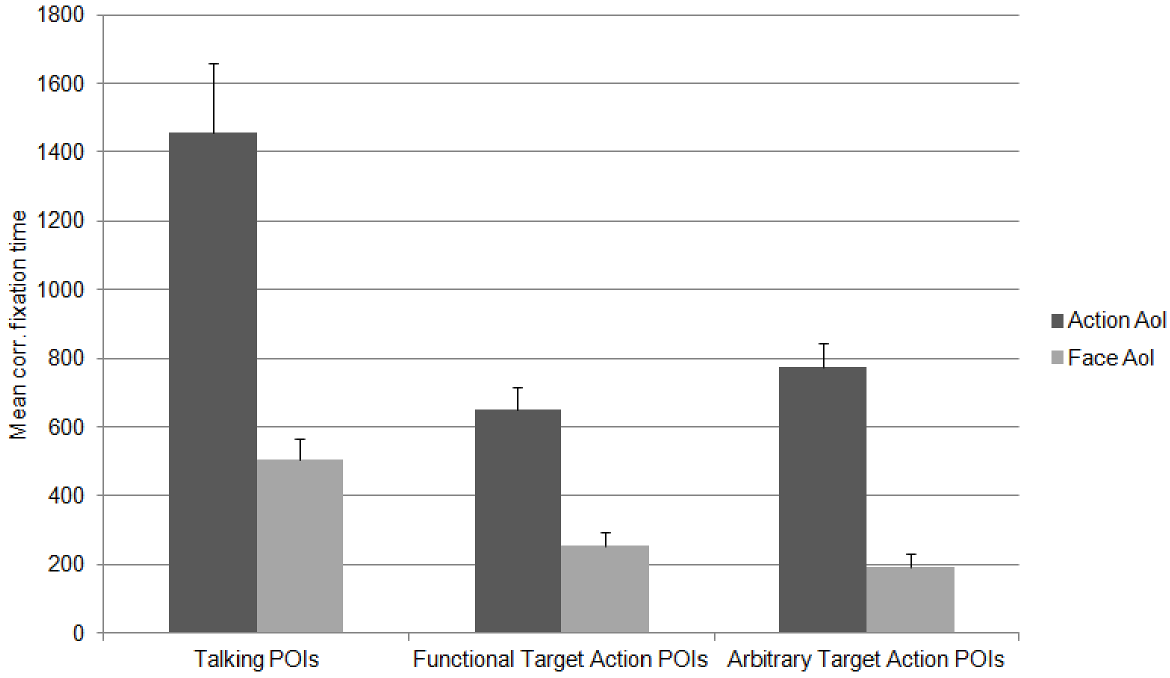

Figure 3. Mean fixation times to the Face AOI and to the Action AOI during Talking POIs, Functional Target Action POIs and Arbitrary Target Action POIs. Error bars indicate standard errors.

Fixation times were analyzed in a RM-ANOVA with the within-subjects factors AOI (Face, Action) and POI (Talking, Functional Target Action, Arbitrary Target Action). Both AOI, $F(1, 22) = 32.65$, $p < .001$, $\eta_p^2 = .60$ and POI, $F(1.1, 24.25) = 31.61$, $p < .001$, $\eta_p^2 = .59$ had a main effect on fixation times and their interaction was also significant, $F(1.31, 28.89) = 7.17$, $p = .008$, $\eta_p^2 = .25$. The main effect of AOI reflects that fixation times to the Action AOI were longer than fixation times to the Face AOI. Post-hoc comparisons of the POI main effect revealed that fixation times during Talking POIs were significantly longer than during both Functional, $SE = 90.92$, $p < .001$, and Arbitrary, $SE = 88.74$, $p < .001$, Target Action POIs. However, fixation times during Functional vs. Arbitrary Target Action POIs did not differ significantly, $SE = 23.39$, $p = .175$. Post-hoc comparisons (t tests) of the AOI × POI interaction showed that the overall effect of AOI, namely that fixation times to the Action

AOI were longer than fixation times to the Face AOI, was consistent across all POIs (all *p*s < .05). Similarly, the overall effect of POI, namely that fixation times during Talking POIs were longer than during the two Target Action POIs, was true for both AOIs (all *p*s < .05).

Amount of fixations to different AOIs during different POIs. Infants' mean amounts of fixations to the Face AOI and the Action AOI during the three different POIs are depicted in Figure 4.

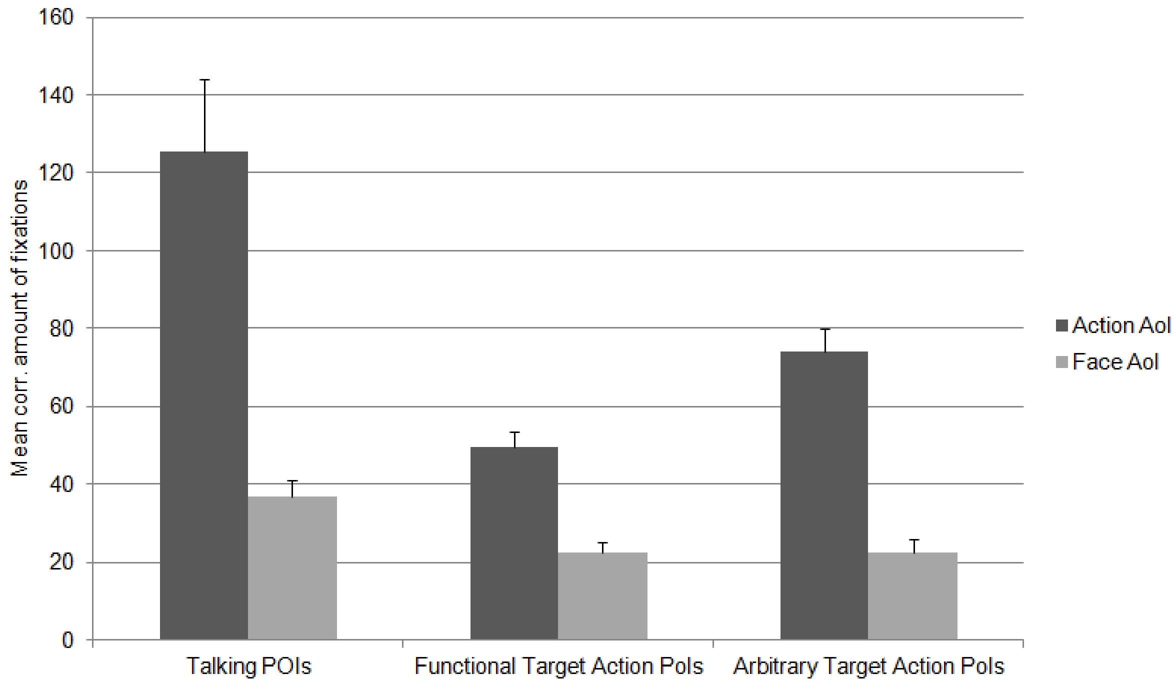

Figure 4. Mean amounts of fixations to the Face AOI and the Action AOI during Talking POIs, Functional Target Action POIs and Arbitrary Target Action POIs. Error bars indicate standard errors.

A RM-ANOVA with the amount of fixations as dependent variable revealed a main effect of AOI, $F(1, 22) = 34.62$, $p < .001$, $\eta_p^2 = .61$, a main effect of POI, $F(1.12, 24.56) = 22.18$, $p < .001$, $\eta_p^2 = .50$, and a significant interaction, $F(1.26, 27.74) = 10.33$, $p = .002$, $\eta_p^2 = .32$. The main effect of AOI showed that the amount of fixations to the Action AOI was larger than the amount of fixations to the Face AOI. Post-hoc comparisons showed that the amount of fixations to the Action AOI was significantly larger during Arbitrary Target Action POIs than during Functional Target Action POIs, $SE = 2.37$, $p < .001$. Post-hoc comparisons (paired sample t tests) of the AOI × POI interaction revealed that the overall effect of AOI, i.e., that the amount of fixations to the Action AOI was larger than the amount of fixations to the Face AOI, was consistent across all POIs (all *p*s < .05). Concerning the effects of POI, the amount of fixations to the Action AOI showed the same pattern as the overall effect, namely that the amount of fixations was lowest during Functional Target Action POIs, medium during Arbitrary Target Action POIs and largest during Talking POIs, with all differences being significant (all *p*s < .05). The amount of fixations to the Face AOI, however, did not differ during Functional vs. Arbitrary Target Action POIs, $t(22) = .02$, $p = .987$.

Amount of different saccade types during different POIs. Table 2 depicts the amount of saccades within and between the Action AOI and the Face AOI as well as between Action/Face AOIs and other screen areas during Talking, Functional Target Action and Arbitrary Target Action POIs.

Table 2

Amount of different saccade types during Talking, Functional Target Action and Arbitrary Target Action POIs

	Talking POIs		Functional Target Action POIs		Arbitrary Target Action POIs	
	M	*SE*	*M*	*SE*	*M*	*SE*
Between Action AOI and Face AOI	0.48	0.06	0.67	0.10	0.57	0.09
Between Action AOI and other screen areas	0.82	0.10	0.56	0.10	0.68	0.11
Between Face AOI and other screen areas	1.11	0.10	0.46	0.10	0.43	0.09
Within the Action AOI	0.54	0.10	1.41	0.16	1.95	0.21
Within the Face AOI	0.82	0.15	0.32	0.08	0.33	0.11

A RM-ANOVA with the within-subject factors 3 POIs × 5 saccade types were conducted using the amount of saccades as dependent variable. The RM-ANOVA yielded a main effect of saccade type, $F(2.24, 49.24) = 14.53$, $p < .001$, $\eta_p^2 = .40$ and a POI × saccade type interaction, $F(4.32, 95) = 25.13$, $p < .001$, $\eta_p^2 = .53$. The factor POI did not have a main effect on the amount of saccades, $F(2, 44) = 2.38$, $p = .104$, $\eta_p^2 = .10$.

Post-hoc comparisons of the factor saccade type showed that the amount of saccades within the Action AOI was significantly larger than the amount of all other saccade types ($SE_{min} = .12$, $SE_{max} = .17$, $p_{min} < .001$, $p_{max} = .002$), most likely due to the objects' movement that infants followed with their gaze during Target Action POIs. The interaction was further analyzed by paired samples t tests. The t tests revealed that the amount of saccades between the Action AOI and the rest of the screen was larger during Talking POIs than during Functional Target Action POIs, $t = 2.472$, $p = .022$. In addition, the amount of saccades between the Face AOI and the rest of the screen was larger during Talking POIs than during both Functional and Arbitrary Target Action POIs ($t = 8.932$, $p < .001$ and $t = 6.358$, $p < .001$, respectively). Furthermore, the amount of saccades within the Action AOI was larger during both Functional and Arbitrary Target Action POIs than during Talking POIs ($t = - 7.436$, $p < .001$ and $t = - 8.178$, $p < .001$, respectively), and it was larger during Arbitrary than during Functional Target Action POIs, $t = - 2.88$, $p = .009$. Finally, the amount of saccades within the Face AOI was larger during Talking POIs than during both Functional and Arbitrary Target Action POIs ($t = 5.110$, $p < .001$ and $t = 3.263$, $p = .004$, respectively).

Item-specific analyses. Next to analyzing deferred imitation and looking data on a composite score level, item level analyses were conducted. Table 3 shows imitation frequencies, mean fixation times and amounts of fixations to the Action AOI, as well as t-test statistics comparing imitation and fixation data between functional and arbitrary target actions in each item.

Table 3

Analyses of target action imitation, as well as mean fixation times and amounts of fixations to the Action AOI

Item	Target action	Frequency of target action being acquired	Mean fixation time to Action AOI[b]	Mean amount of fixations to Action AOI[b]
Tin	Functional	13.0	774.71 (515.43)	76.14 (52.76)
	Arbitrary	8.7	1543.15 (1080.55)	158.14 (118.63)
	t	.569	- 3.892	- 3.599
	p	.575	.001	.002
Pig	Functional	21.7	422.72 (211.16)	46.29 (22.77)
	Arbitrary	13.0	771.37 (383.49)	64.94 (38.24)
	t	1.0	- 5.924	- 3.711
	p	.328	< .001	.001
Bowl	Functional	30.4	419.51 (166.21)	29.63 (11.99)
	Arbitrary	0.0	540.50 (324.09)	66.00 (32.28)
	t	3.102	- 2.152	- 6.048
	p	.005	.043	.000
Mouse	Functional	8.7	912.37 (942.34)	59.07 (51.85)
	Arbitrary	0.0	408.76 (347.44)	24.29 (18.21)
	t	1.447	3.250	3.626
	p	.162	.004	.001
Drum	Functional	17.4	718.45 (836.27)	36.89 (44.07)
	Arbitrary	0.0	615.98 (495.28)	56.35 (42.88)
	t	2.152	.878	- 2.964
	p	.043	.390	.007

[a] Standard deviations in parentheses.

The item-level t tests demonstrate that the overall findings are not replicated consistently across the items. Whereas in the items tin, pig and bowl fixation times to the Action AOI were higher during arbitrary target actions, in the items mouse and drum fixation times were higher during the functional target actions. The same holds true for mean amounts of fixations to the Action AOI with the exception of the item drum. In addition, an analysis of correlations between the duration of noise produced by the target actions and imitation frequency, fixation times and amounts of fixations revealed that neither the imitation frequency (r = -.083, p = .819) nor the fixation times (r = -.437, p = .207) or amounts of fixations (r = -.560, p = .092) correlated with the duration of noise produced by the target actions.

Relations Between Infants' Looking Behavior and Deferred Imitation

The amount of functional target actions infants learned from the demonstration (i.e., the sum of functional target actions that were performed in the test, but not in the baseline phase)[2] and all gaze variables concerning functional POIs and Talking POIs were transformed into dichotomous variables via median split and analyzed by χ^2 tests. None of the tests led to a significant result ($\chi^2_{min.}$ = 0.02, $\chi^2_{max.}$ = 3.16; $p_{min.}$ = .08, $p_{max.}$ = .90), indicating that there was no relation between the gaze variables and the imitation score of functional target actions. An analysis of biserial correlations between the gaze variables and the amount of newly learned functional target actions ($r_{min.}$ = .01, $r_{max.}$ = .50; $p_{min.}$ = .02, $p_{max.}$ = .99), as well as independent samples t tests with the factor high vs. low amount of newly learned functional target actions led to the same conclusion ($t_{min.}$ = .07, $t_{max.}$ = 1.39; $p_{min.}$ = .07, $p_{max.}$ = .96).

Discussion

The present study analyzed how perceptual processes during action demonstration influence selective imitation of functional over arbitrary actions in a sample of 12-month-old infants. In line with the memory effect hypothesis, the behavioral results of the present study

[2] Imitation scores of arbitrary target actions were omitted in this analysis due to lack of variance.

show that infants performed more target actions in the deferred imitation than in the baseline phase replicating the well-established memory effect (e.g., Barr et al., 1996).

In line with the functionality effect hypothesis, infants imitated significantly more functional than arbitrary target actions in the deferred imitation phase. This result replicates findings by Óturai et al. (2012) using the identical target actions in a sample of 12-month-olds, thus showing selective imitation in a different sample. In comparison to the study by Óturai et al. (2012), however, target action performance during deferred imitation testing was descriptively lower due to negative impact of video demonstration of target actions. This phenomenon is known as the video deficit effect, i.e., that infants and children learn less from television than they learn from live presentations (for a review see Barr, 2010). Nevertheless, despite lower imitation rates, data still show significant memory and functionality effects in line with findings by Óturai et al. (2012).

Eye-tracking data, first of all, reflect that infants looked at the demonstration screen ca. ¾ of the time, and they looked longer towards Action AOIs than towards the Face AOI across all periods of interest (Talking POIs, Functional Target Action POIs, Arbitrary Target Action POIs). This finding indicates that infants are able to continuously focus their attention on the relevant areas of interest, i.e., they follow the target object, and are not distracted by the model, nor do they lose interest in the presentation. This holds true during both functional and arbitrary action demonstration, as well as during talking periods. Second, in contrast to our initial assumption, results regarding our selective attention hypothesis show that, giving the overall finding, infants' fixation times to the Action AOI did not differ between functional and arbitrary target actions. Thus, selective imitation in the present study cannot be explained by selective visual attention towards functional target actions during the demonstration phase. This interpretation is strengthened by the statistical tests showing no relations between gaze behavior and imitation performance.

However, the analysis of amounts of fixations and saccades showed that infants had significantly more fixations, and also more saccades, in the Action AOI during Arbitrary Target Action POIs than during Functional Target Action POIs. Although these findings do not contradict our interpretation that selective imitation is not a result of selective attention towards functional target actions, they nevertheless indicate that infants' imitation was not entirely independent of their looking behavior. Infants had more fixations (and saccades) on the type of target actions they did not imitate (arbitrary actions). From our perspective, these findings indicate that infants process and encode these two types of target action in qualitatively different ways. Nevertheless, this needs to be investigated by further studies, as the role of perceptual differences between functional and arbitrary target actions cannot be excluded in the present data. As the item-level findings indicate, perceptual and conceptual item features influence infants' looking behavior. This finding is also in line with recent findings by Elsner, Pfeifer, Parker, and Hauf (2013).

Although the findings suggest that selective imitation does not rely simply on selective visual attention towards one kind of target action, the current study design does preclude drawing any strong conclusions on the theoretical conceptualization of selective imitation. The present current findings do not provide an answer to the question when exactly (during action encoding, storage, or retrieval) target actions to be imitated are being selected and they do not favor either the low-level, perception-action matching based theories (Paulus et al., 2011b) or the higher-level, interpretation based theories of selective imitation (e.g., Király, 2009; Király, Csibra, & Gergely, 2013). Instead, the findings strengthen both theories by showing that whatever mechanisms lead to selective imitation, they take place after both kinds of target action have been perceived. These questions need to be further investigated with different research designs in future studies.

The current results are also relevant for research analyzing the video-deficit effect. In the current study, 12-month-olds showed clear evidence of learning some target actions from a video presentation. This result is in line with previous findings showing that 12-month-olds are able to imitate from a televised model (Barr, Muentener, & Garcia, 2007; Klein, Hauf, & Aschersleben, 2006). Although it has been suggested that potential decreases in (deferred) imitation performance due to the video deficit are related to less focused attention towards video representations (Barr & Hayne, 1999), in our study, infants spent about ¾ of the time during target action demonstration fixating the screen. This rather high screen fixation time does not support the idea of insufficient attention towards a video demonstration. However, as the present study had no live demonstration control group, this assumption needs to be tested in future studies.

Additionally, for memory-oriented deferred imitation research, the present results demonstrate that inter-individual differences in deferred imitation performance are not due to perceptual processes (selective attention). This finding is also interesting to note from a diagnostician perspective in that a potential performance-competence gap is not due to infants just not paying attention to target action demonstrations. This provides additional measurement validity for deferred imitation testing.

One confining experimental factor is that infants' looking options were limited. The demonstration situation we used in the present study was a typical laboratory deferred imitation study with an experimenter sitting at the table in a standardized room demonstrating specific actions with a small number of objects. But despite the lack of distractor stimuli, infants might have looked differently to arbitrary than to functional actions in a number of ways, e.g., turn away from the screen more often during less interesting action demonstrations. However, the amount of on-screen fixations did not differ between functional and arbitrary target actions. Additionally, the amount of saccades between the Face AOI and the Action AOI, as well as between the Action AOI and the rest of the screen did not differ between functional and arbitrary target actions, either. Thus, infants did not look away from the ongoing action more frequently during one action type than during the other. But notwithstanding, further studies could vary ecological validity in that, for example, distractor objects could be presented on the screen in a classical experimental deferred imitation situation or the demonstration situation could take place in a noisier, more natural environment.

A second methodological factor important to discuss is the rather high attrition rate due to two sources of attrition. First, a good calibration and validation necessitates little movement of the subject. As 12-month-old infants are motorically rather active (they just learned or are about to learn to walk), a reliable proper gaze measurement was not realizable in a number of infants even while using interesting attention getters. Second, as is typical in deferred imitation studies, some of the infants refused to play with more than one object rendering an exact measurement of deferred imitation impossible. As the present study analyzed a combination of eye-tracking and deferred imitation in 12-month-olds, it is reasonable that the attrition rate was higher than usual.

Next to varying ecological validity, future (deferred) imitation research analyzing infants' looking behavior might also analyze relations between the looking behavior to specific objects (e.g., an enlarged version of specific objects is shown on the screen), infants' (predictive) looking to their respective salient and not so salient parts and infants' deferred imitation performance. Last but not least, typical experimental factors (i.e., number of demonstrations, experimenter, experimental context, among others) and item-specific effects might be varied in line with the former study proposal.

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Appendix A

Sizes of Areas of Interest in pixels and in visual angles (from a distance of 600 mm, in parentheses).

Item	Demonstration	POI	Face AOI		Action AOI	
			width	height	width	height
Tin can	1.	Talking	145 (6.56)	165 (6.96)	37.5 (1.71)	50 (2.21)
		Functional	150 (6.79)	170 (7.15)	105 (4.63)	160 (7.07)
		Arbitrary	140 (6.34)	170 (7.16)	105 (4.74)	65 (2.91)
	2.	Talking	140 (6.35)	165 (6.96)	37.5 (1.72)	47.5 (2.10)
		Functional	150 (6.79)	170 (7.15)	115 (5.07)	155 (6.86)
		Arbitrary	145 (6.56)	170 (7.16)	100 (4.52)	70 (3.13)
	3.	Talking	145 (6.56)	160 (6.75)	35 (1.60)	47.5 (2.10)
		Functional	145 (6.57)	165 (6.94)	115 (5.04)	145 (6.41)
		Arbitrary	145 (6.56)	170 (7.16)	145 (6.44)	85 (8.25)
	4.	Talking	140 (6.34)	160 (6.75)	40 (1.83)	45 (1.99)
		Functional	150 (6.79)	170 (7.15)	110 (4.83)	145 (6.40)
		Arbitrary	140 (6.35)	170 (7.16)	90 (4.08)	85 (3.80)
Pig and hat	1.	Talking	135 (6.12)	165 (6.94)	212.5 (9.35)	110 (4.91)
		Functional	150 (6.78)	170 (7.13)	260 (11.27)	180 (8.03)
		Arbitrary	160 (7.22)	175 (7.34)	160 (6.97)	210 (9.33)
	2.	Talking	145 (6.56)	170 (7.13)	260 (11.21)	120 (5.36)
		Functional	155 (7.00)	175 (7.34)	295 (12.56)	185 (8.25)
		Arbitrary	155 (7.00)	170 (7.13)	160 (6.97)	190 (8.47)
	3.	Talking	145 (6.55)	165 (6.94)	250 (10.80)	110 (4.91)
		Functional	150 (6.77)	175 (7.34)	265 (11.65)	180 (8.03)
		Arbitrary	150 (6.78)	170 (7.13)	145 (6.35)	200 (8.90)
	4.	Talking	135 (6.11)	160 (6.74)	237.5 (10.27)	110 (4.91)
		Functional	150 (6.77)	170 (7.13)	260 (11.19)	190 (8.47)
		Arbitrary	150 (6.78)	170 (7.13)	160 (6.95)	215 (9.54)
Bowl and stirrer	1.	Talking	150 (6.79)	170 (7.15)	95 (4.33)	65 (2.87)
		Functional	195 (8.70)	180 (7.54)	295 (12.70)	210 (9.35)
		Arbitrary	160 (7.23)	175 (7.35)	200 (8.78)	150 (6.71)
	2.	Talking	155 (7.00)	175 (7.35)	95 (4.28)	70 (3.10)
		Functional	195 (8.74)	180 (7.54)	225 (9.98)	200 (8.92)
		Arbitrary	165 (7.47)	180 (7.54)	225 (9.82)	135 (6.03)
	3.	Talking	160 (7.23)	172.5 (7.25)	115 (5.23)	65 (2.87)
		Functional	180 (8.04)	180 (7.54)	280 (12.05)	225 (10.00)
		Arbitrary	170 (7.67)	180 (7.54)	230 (10.01)	160 (7.15)
	4.	Talking	155 (7.00)	170 (7.15)	92.5 (4.17)	67.5 (2.98)
		Functional	170 (7.67)	175 (7.34)	230 (10.18)	210 (9.36)
		Arbitrary	165 (7.47)	180 (7.55)	215 (9.40)	195 (8.70)
Mouse	1.	Talking	140 (6.34)	160 (6.75)	102.5 (4.58)	42.5 (1.88)
		Functional	155 (7.00)	175 (7.35)	105 (4.69)	95 (4.24)
		Arbitrary	150 (6.78)	175 (7.35)	190 (8.36)	145 (6.48)
	2.	Talking	150 (6.78)	162.5 (6.85)	177.5 (7.79)	90 (4.01)
		Functional	150 (6.78)	170 (7.15)	115 (5.10)	100 (4.47)
		Arbitrary	150 (6.78)	170 (7.15)	205 (8.98)	150 (6.71)

	3.	Talking	145 (6.55)	170 (7.16)	102.5 (4.56)	40 (1.77)
		Functional	150 (6.78)	175 (7.35)	105 (4.67)	95 (4.24)
		Arbitrary	150 (6.78)	170 (7.15)	210 (9.19)	155 (6.93)
	4.	Talking	140 (6.34)	160 (6.75)	100 (4.46)	47.5 (2.10)
		Functional	150 (6.77)	170 (7.15)	105 (4.67)	100 (4.47)
		Arbitrary	145 (6.78)	170 (7.15)	220 (9.59)	145 (6.48)
Drum	1.	Talking	135 (6.11)	170 (7.15)	75 (3.41)	55 (2.43)
		Functional	160 (7.23)	175 (7.35)	135 (6.04)	145 (6.48)
		Arbitrary	175 (7.87)	175 (7.34)	175 (7.77)	160 (7.15)
	2.	Talking	140 (6.34)	165 (6.94)	82.5 (3.75)	55 (2.43)
		Functional	155 (7.00)	175 (7.35)	125 (5.61)	145 (6.48)
		Arbitrary	170 (7.65)	175 (7.35)	175 (7.76)	165 (7.38)
	3.	Talking	140 (6.34)	170 (7.15)	75 (3.41)	55 (2.43)
		Functional	155 (7.00)	175 (7.35)	80 (3.60)	135 (6.04)
		Arbitrary	160 (7.23)	175 (7.35)	170 (7.55)	160 (7.15)
	4.	Talking	140 (6.34)	170 (7.15)	80 (3.63)	55 (2.43)
		Functional	150 (6.78)	180 (7.54)	125 (5.60)	140 (6.26)
		Arbitrary	165 (7.44)	170 (7.15)	165 (7.33)	160 (7.15)

Appendix B

Durations of Periods of Interest in frames

Item	Demonstration	POI	Duration (frames)
Tin can	1.	Talking	55
		Functional	26
		Arbitrary	20
	2.	Talking	69
		Functional	28
		Arbitrary	19
	3.	Talking	62
		Functional	28
		Arbitrary	20
	4.	Talking	28
		Functional	25
		Arbitrary	17
Pig and hat	1.	Talking	60
		Functional	34
		Arbitrary	35
	2.	Talking	73
		Functional	26
		Arbitrary	39
	3.	Talking	51
		Functional	33
		Arbitrary	38
	4.	Talking	43
		Functional	26
		Arbitrary	40
Bowl and stirrer	1.	Talking	65
		Functional	104
		Arbitrary	28
	2.	Talking	69
		Functional	108
		Arbitrary	22
	3.	Talking	47
		Functional	107
		Arbitrary	26
	4.	Talking	36
		Functional	105
		Arbitrary	21
Mouse	1.	Talking	58
		Functional	45
		Arbitrary	65
	2.	Talking	60
		Functional	49
		Arbitrary	67
	3.	Talking	33
		Functional	46
		Arbitrary	73

	4.	Talking	27
		Functional	44
		Arbitrary	74
Drum	1.	Talking	58
		Functional	35
		Arbitrary	72
	2.	Talking	68
		Functional	32
		Arbitrary	60
	3.	Talking	40
		Functional	32
		Arbitrary	60
	4.	Talking	47
		Functional	35
		Arbitrary	71

Paper 3

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Relations between 18-month-olds' gaze pattern and target action performance: A deferred imitation study with eye tracking

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ABSTRACT

Deferred imitation studies are used to assess infants' declarative memory performance. These studies have found that deferred imitation performance improves with age, which is usually attributed to advancing memory capabilities. Imitation studies, however, are also used to assess infants' action understanding. In this second research program it has been observed that infants around the age of one year imitate selectively, i.e., they imitate certain kinds of target actions and omit others. In contrast to this, two-year-olds usually imitate the model's exact actions. 18-month-olds imitate more exactly than one-year-olds, but more selectively than two-year-olds, a fact which makes this age group especially interesting, since the processes underlying selective vs. exact imitation are largely debated. The question, for example, if selective attention to certain kinds of target actions accounts for preferential imitation of these actions in young infants is still open. Additionally, relations between memory capabilities and selective imitation processes, as well as their role in shaping 18-month-olds' neither completely selective, nor completely exact imitation have not been thoroughly investigated yet. The present study, therefore, assessed 18-month-olds' gaze toward two types of actions (functional vs. arbitrary target actions) and the model's face during target action demonstration, as well as infants' deferred imitation performance. Although infants' fixation times to functional target actions were not longer than to arbitrary target actions, they imitated the functional target actions more frequently than the arbitrary ones. This suggests that selective imitation does not rely on selective gaze toward functional target actions during the demonstration phase. In addition, a post hoc analysis of interindividual differences suggested that infants' attention to the model's social-communicative cues might play an important role in exact imitation, meaning the imitation of both functional and arbitrary target actions.

1. Introduction

Infants' imitation has been subject to a wide range of developmental studies. On the one hand, imitation of observed actions after a retention interval (deferred imitation) has been taken as a measure of infants' declarative memory performance (e.g., Meltzoff, 1985, 1988). Infants show deferred imitation of a small number of target actions from about six months of age on (Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999; Heimann & Nilheim, 2004; Kressley-Mba, Lurg, & Knopf, 2005).

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With increasing age, infants' deferred imitation performance improves rapidly, which is usually attributed to improving information processing and memory capabilities (Barr et al., 1996; Bauer, 2005; Hayne, 2004; Jones & Herbert, 2006; Knopf, Goertz, & Kolling, 2011). The age-related improvement of deferred imitation performance is shown by the increasing amount of target actions infants are able to imitate, suggesting an improvement in the capacity of infants' memory (Barr et al., 1996; Collie & Hayne, 1999; Elsner, Hauf, & Aschersleben, 2007; Kolling, Goertz, Frahsek, & Knopf, 2010). With increasing age, infants also become able to show deferred imitation after longer delay intervals, suggesting an improvement in retention (Barr & Hayne, 2000; Herbert & Hayne, 2000). Additionally, older infants need fewer repetitions of target action demonstration to successfully engage in deferred imitation, which suggests that encoding also becomes more efficient with age (e.g., Barr et al., 1996).

On the other hand, imitation methods have been applied to investigate infants' understanding of observed actions (see Elsner, 2007 for a review) as well as psychological states, such as goals and intentions, of the persons demonstrating these actions (e.g., Bellagamba & Tomasello, 1999; Carpenter, Akhtar, & Tomasello, 1998; Meltzoff, 1995). Within this line of research it has been found that in a pedagogical context (i.e., when the model uses ostensive cues to communicate the target actions to the child, see Csibra & Gergely, 2006; Gergely & Csibra, 2005; Király, Csibra, & Gergely, 2013) infants around the age of one year usually imitate selectively. This means that infants imitate certain kinds of target action more frequently than others, according to the actions' perceived intentionality (Carpenter et al., 1998), goal-relevance (Brugger, Lariviere, Mumme, & Bushnell, 2007), or efficiency (Gergely, Bekkering, & Király, 2002; Schwier, van Maanen, Carpenter, & Tomasello, 2006). In contrast, children from about the age of two years have been repeatedly found to imitate the model's actions exactly (Nagell, Olguin, & Tomasello, 1993; Nielsen, 2006). 18-month-olds' imitate neither as selectively as 12-month-olds, nor as exactly as 24-month-olds. For example, Nielsen (2006) found that while 12-month-olds only reproduced the model's specific actions when they were given a rational reason to do so and 24-month-olds imitated the model's specific actions in all conditions, 18-month-olds imitated selectively when the model acted aloof, but they were as likely to reproduce the specific actions as the actions' outcomes when the model acted socially, irrespective of the apparent logic of the actions. Similarly, Tennie, Call, and Tomasello (2006) found that 12-month-olds typically reproduced the goal of the target action, ignoring the exact movement, 18-month-olds reproduced the goal by copying the exact movement if the target action was demonstrated by a model and 24-month-olds reproduced the goal by copying the exact movement both when the target action was presented by a model and when the target object was seemingly moving on its own (ghost condition). Carpenter, Call, and Tomasello (2005) also reported that in a condition where infants were more likely to copy the exact movement than the action's goal state, 18-month-olds did so more frequently than 12-month-olds. Additionally, in a deferred imitation task varying the functionality of target actions, 12-month-olds were found to imitate only those target actions that required specific object properties (*functional actions*) and to completely omit target actions that could be performed on any kind of object (*arbitrary actions*). In contrast, 18-month-olds imitated both kinds of actions, but still reproduced more functional than arbitrary ones (Óturai, Kolling, Rubio Hall, & Knopf, 2012).

Although the finding that 18-month-olds imitate more exactly than 12-month-olds within the same task constraints seems to be consistent across imitation studies applying a pedagogical setting in infancy (see also Gergely & Király, 2003, as cited by Gergely, 2003), other studies report selective imitation in older children (McGuigan & Graham, 2010; McGuigan & Whiten, 2009; McGuigan, Makinson, & Whiten, 2011). This apparent contradiction might rely on task characteristics such as task complexity or the lack of pedagogical cues in studies with older children (e.g., McGuigan & Graham, 2010; McGuigan & Whiten, 2009; McGuigan et al., 2011; Wood, Kendal, & Flynn, 2012), as well as on different motivations and social pressure in infancy and toddlerhood vs. preschool age (Over & Carpenter, 2012a, 2012b). However, the present paper does not aim to provide a general account on imitation across all different task contexts and across the total preschool age. Instead, we focus on selective vs. more exact imitation in infancy, as it has been reported in (deferred) imitation studies applying a child-directed communication of target actions.

Several theoretical accounts have been proposed to explain selective imitation. Some of these claim that selective imitation can be explained by lower level, automatic processes, such as direct mapping of the observed actions onto one's own motor repertoire, i.e., motor resonance, combined with action-effect binding (Hauf & Prinz, 2005; Meltzoff, 2007; Paulus, Hunnius, Vissers, & Bekkering, 2011a, 2011b). Although these theories can explain some important issues related to selective imitation – e.g., why actions with salient effects are imitated more frequently than actions without salient effects (Elsner, 2007), they do not provide an explanation for age differences in selective vs. exact imitation.

These age differences can be better explained by theories proposing both that imitation involves some interpretation of the presented actions, and that the nature of these interpretations changes with development. Gergely (2003) describes a shift from teleological to mentalizing action interpretation: 14-month-olds interpret the observed actions in terms of their visible outcomes and situational constraints, whereas 18-month-olds attribute a communicative, teaching intention to the model. As a result, 14-month-olds only imitate the model's actions if those seem to be efficient (Gergely et al., 2002), while 18-month-olds exactly imitate the model's actions irrespective of their apparent efficiency (Gergely & Király, 2003, as cited by Gergely, 2003; cf. Nielsen, 2006). This argumentation is in line with the idea of a developmental change from object-centered to social imitation, as claimed by Uzgiris (1981), already. Uzgiris proposed that while 10-month-olds' imitation is guided by a cognitive motivation to learn about objects and actions, infants aged 16 months and older also use imitation to maintain the social interaction with the model.

Empirical evidence underlines the importance of the social-communicative context in guiding infants' imitation in that the more social engagement is possible, the more exact infants' imitation will be (Király, 2009; Nielsen, 2006; Nielsen, Simcock,

& Jenkins, 2008). Although it has been theoretically described that not only the model's social-communicative cues, but also the learner's sensitivity to these cues are necessary to establish the pedagogical context enabling exact imitation (Csibra & Gergely, 2006; Gergely & Csibra, 2005), studies so far have only considered the model's role and did not investigate infants' attention to the model's social-communicative cues. Nevertheless, it can be assumed that different levels of attention to the model's social-communicative cues can lead to differences in infants' imitative behavior within the same age group. With respect to individual differences, 18-month-olds are particularly interesting, as their neither completely selective, nor completely exact imitation shown on a group level might result from some infants imitating more exactly than others.

Taken together, the quantitative improvement in infants' imitation ability across age (Barr et al., 1996; Elsner et al., 2007; Kolling et al., 2010) has been explained by advancing information processing and memory capabilities (Barr et al., 1996; Bauer, 2005; Hayne, 2004; Jones & Herbert, 2006; Knopf et al., 2011). As an explanation for age differences in selective vs. exact imitation (Nielsen, 2006; Óturai et al., 2012; Tennie et al., 2006), however, changes in infants' action interpretations due to the emerging sensitivity to social-communicative cues (Gergely, 2003) and changes in infants' motivation (Uzgiris, 1981) have been suggested. Although memory capabilities, infants' action interpretation and motivation are likely to interact in guiding infants' imitative behavior, their relations and the underlying processes are still unclear.

In order to tackle both infants' information processing and their attention to the social-communicative context of imitation, we assessed infants' gaze toward the target actions and the model during the demonstration phase of a deferred imitation task, using a fully automated remote eye tracker. Eye tracking has been proved a suitable method to assess what infants and children are attending to (e.g., Aslin & McMurray, 2004) and in a couple of studies it has already been applied to investigate the relations between participants' gaze and imitation performance. In one of these studies, infants' gaze toward videotaped target actions presented either with or without specific constraints, as well as infants' subsequent imitation were investigated. Although the findings of this study do not allow direct analysis of the relations between action observation and imitation (as imitation performance was only found in one out of three actions), they nevertheless showed that both situational constraints and movement characteristics affect infants' allocation of attention to different parts of the display screen (Elsner, Pfeifer, Parker, & Hauf, 2013). In another study relations between visual attention to nonmeaningful gestures and imitation precision were found in children with autism (Vivanti, Nadig, Ozonoff, & Rogers, 2008). Relations between visual attention and imitation were also found in a study that did not involve eye tracking. Here, infants' selective imitation was found to rely on insufficient encoding due to perceptual distraction (Beisert et al., 2012). In contrast with these findings, other researchers found that infants' gaze toward the target actions did not relate to target action imitation. Esseily (2012) reports that infants looked longer to the target action when the model was communicating than when the model was silent. However, enhanced visual attention to the target action in the communicating condition did not lead to better imitation performance. Kirkorian (2012) found that infants attended more to the target action when the model was a familiar character and more to the model when the model was unfamiliar. However, increased attention to the target action in the familiar character condition did not lead to better imitation performance. In addition, Kolling, Óturai and Knopf (2013) found that although 12-month-old infants did not attend more to functional than to arbitrary target actions, they imitated the former more frequently.

The main goal of the present study was to further investigate the linkage between infants' gaze behavior during action demonstration and later action imitation by replicating the Kolling et al. study with 18-month-olds and extending the former results. Another goal of the present study was to investigate two possible relations between memory capabilities and selective imitation processes. The first possible relation is that both infants' age-related improvement of deferred imitation performance and the shift from selective toward more exact imitation rely primarily on infants' improving information processing and memory capabilities. Consider, for example, selective imitation of functional as opposed to arbitrary target actions (Kolling et al., 2013; Óturai et al., 2012). Arbitrary target actions are less connected to the target objects than functional ones, so they might be more difficult to retain and reproduce. If this was the case, infants would need more attention to arbitrary target actions and better memory capabilities in order to retain and reproduce these actions. Consequently, infants' attention to and imitation of arbitrary target actions would be related. Additionally, imitation rates of arbitrary target actions would be related to imitation rates of functional target actions. The second possible relation is that the developmental shift from selective toward more exact imitation, based on interpretational changes and an emerging social orientation, also accounts for the quantitative improvement in infants' deferred imitation performance in that more exact imitation means the reproduction of more different kinds – and thus a larger number – of target actions. In this case, more attention to the social-communicative context of the imitation task would be related to imitation of arbitrary target actions. Additionally, imitation rates of arbitrary target actions would not be related to imitation rates of functional target actions.

Findings by Hauf (2009) strengthen the view that eye tracking is a suitable method to assess the relations between action observation and action production. Infants in this study looked longer to the action area when the action was presented with an object they had own experience with than when it was presented with an unfamiliar object. Additionally, in the action production phase infants were more likely to choose the object previously being acted on by the model than another object which was presented stationary in the video. Besides demonstrating strong relations between action observation and action production, these findings imply that for studies investigating gaze behavior in an imitation task a baseline phase instead of an independent control group might be more appropriate in order to increase infants' motivation to attend to the target actions.

Therefore, we tested a group of 18-month-old infants in a within-subjects design deferred imitation study using both functional and arbitrary target actions, and assessed infants' gaze during the demonstration phase. First, we assumed that infants would engage in deferred imitation, indicating a memory effect and replicating a series of previous findings (e.g., Kolling et al., 2010). Second, we expected infants to imitate both functional and arbitrary target actions, with the imitation rate of functional target actions being higher than the imitation rate of arbitrary actions, as a sign of neither completely selective, nor completely exact imitation (Óturai et al., 2012). Third, we expected that infants' overall gaze pattern would not be related to the pattern of their target action imitation, strengthening the findings that selective imitation is based on processes other than selective visual attention during action observation (Esseily, 2012; Kirkorian, 2012; Kolling et al., 2013). Analyzes regarding the two possible relations between memory capabilities and selective imitation processes were explorative. Although we did not expect overall relations between gaze and deferred imitation performance (i.e., a clear advantage of functional target actions in infants' looking times, corresponding with an advantage in deferred imitation), finer-grained relations were investigated.

2. Method

2.1. Participants

$N = 20$[1] healthy, full-term infants (10 girls) at the age of 18 months were tested in this study (age in days: 537–563, $M = 553.15$, $SD = 7.56$). Infants had a mean birth weight of $M = 3301.35$ g ($SD = 411.02$), a mean 5 min APGAR score of 9.35 ($SD = .81$) and they were all born after at least 37 weeks of gestation ($M = 39.8$, $SD = .89$). Additional two infants were tested but excluded from the final analysis because of eye tracking calibration or validation failure.

2.2. Materials

2.2.1. Action demonstration video

The action demonstration video showed a male model sitting at a table, facing the camera and thus the observing infant. Each item, i.e., each pair of a functional and an arbitrary target action performed on the same object, was demonstrated three times in a row. To establish a social-communicative context, the model talked to the infant at the beginning of every demonstration. He said: "Look, I will show you something! . . . Look, I will show it again".

2.2.2. Target actions and objects

The actions were adapted from the Frankfurt Imitation Test for 18-month-old infants (FIT 18, see Goertz, Kolling, Frahsek, & Knopf, 2008; Óturai et al., 2012). Two target actions were demonstrated on each of the six objects: a functional and an arbitrary one. Functional actions are those that require specific object properties and are thus strongly connected to the objects, whereas arbitrary actions do not require specific object properties and thus could be performed on a wide range of objects (Óturai et al., 2012). The items and the corresponding arbitrary and functional target actions are presented in Table 1.

Presentation order of target actions was varied across items. The second, the third and the sixth item started with the functional target action, whereas the first, the fourth and the fifth one started with the arbitrary target action.

2.2.3. Eye-tracking system

Infants' eye movements were recorded using an EyeLink Remote 1000® eye tracker (SR Research Ltd.). The EyeLink Remote 1000® operates at a sampling rate of 500 Hz with no loss of spatial resolution. Its average accuracy is 0.5° and it allows head movements of 22 cm × 18 cm × 20 cm without accuracy reduction. The infra-red eye-tracking camera was fixed beneath a 17″ LCD-screen mounted on a hydraulic arm, allowing easy positioning for each individual infant. The action demonstration video was presented on the eye tracker screen using a resolution of 704 × 576 pixels, which corresponds with a width of 31.64 visual angles and a height of 25.36 visual angles from a viewing distance of 0.6 m. Stimulus presentation and eye movement recording were controlled by the experimenter via two personal computers in an adjacent room.

2.3. Procedure

Prior to testing, the caregiver and the infant were escorted to a waiting room where the infant had the possibility to play and get familiar with the experimenter. During this time the experimenter explained the purpose and procedure of the study and obtained informed consent from the caregiver. In addition, caregivers gave information about pregnancy, infants' postpartum health state and additional life circumstances. The procedure of the study consisted of a baseline testing phase, a demonstration phase with eye tracking, a delay and an imitation phase.

2.3.1. Baseline testing

Behavioral baseline testing took place in a sparsely furnished laboratory room where the infant was seated on the caregiver's lap at a table, opposite to the experimenter. Caregivers were asked not to interact with their infants and especially

[1] The present study was in accordance with ethical guidelines of the American Psychological Association (APA) and the Society for Research in Child Development (SRCD).

Table 1
Target objects and actions with operational definitions.

Item	Objects	Target action 1	Target action 2
Ship		Taking the ship from one hand to the other and back *Will be coded as yes, if the child takes the ship from one hand to the other*	**Putting a hand into the ship and waving** *Will be coded as yes, if the child puts a hand into the ship*
Cow and metal box		**Clicking the box on the cow's belly** *Will be coded as yes, if the child clicks the box on the cow's belly, even if the magnets do not hold*	Lifting the cow and placing it back on the table ("jumping") *Will be coded as yes, if the child lifts the cow and places it back on the table, regardless if the box is on the cow's belly*
Mouse		**Shutting the mouse four times (sound effect)** *Will be coded as yes, if the child shuts the mouse, even if it is too weak to produce a sound*	Sliding the mouse on a curvy path *Will be coded as yes, if the child pushes the mouse forward on the table*
Frog and ring		Sitting the frog in the ring and sliding it to and fro *Will be coded as yes, if the child slides the frog to and fro on the table, regardless if the frog is sitting in the ring*	**Putting a finger into the frog and holding it upright** *Will be coded as yes, if the child puts a finger in the frog*
Drum		Sliding the drumstick around the drum *Will be coded as yes, if the child slides the drum-stick around or next to the drum*	**Pressing the red but-ton (sound effect)** *Will be coded as yes, if the child presses the red but-ton on the drum*
Duck and octopus		**Sitting the duck on the octopus** *Will be coded as yes, if the child places the duck on the octopus*	Turning the duck *Will be coded as yes, if the child turns the duck, regardless if the duck is sit-ting on the octopus*

Note. Functional target actions are shown in boldface, arbitrary target actions in regular font, and operational definitions in italic.

not to give hints about the functions and names of the objects. After approximately two minutes of warm-up play with an attractive toy, baseline testing began. The experimenter took the first object from a hidden container and placed it on the table in front of the infant. The experimenter directed the infant's attention to the object by saying: "Look, [Name]! You can play with this." If necessary, the experimenter repeated the encouragement to play with the object. After 30 s the experimenter removed the object and placed the next one on the table, saying: "Look, [Name], now you can play with this one." The same procedure was repeated for all target objects. The infant's playing behavior was videotaped by two cameras.

2.3.2. Demonstration of target actions and eye-tracking

Subsequent to baseline testing, the laboratory room was left and the infant and caregiver were escorted to the eye-tracking room. A small eye-tracking reference point sticker was attached to the infant's forehead, and then the infant was seated on the caregiver's lap in front of the eye tracker screen. Infants' distance from the eye tracker (optimal distance: 0.6 m), as well as pupil and corneal reflection thresholds were adjusted. During this short set up, infants' attention was directed to the screen by two moving cartoon snails.

Calibration and validation were performed using subsequently presented images of looming concentric white circles on a black background with a centered red dot at the following five locations: 359.5/287.5, 359.5/526.1, 359.5/48.9, 675.9/287.5, 43.1/287.5 (in pixels). The maximum size of the circles was 80 × 80 pixels. Manual calibration mode was used to increase calibration and validation accuracy. The experimenter judged a fixation to a calibration target as correct, if (1) both pupil and corneal reflection were visible, (2) the crosshair indicating the subject's gaze was stable, and (3) the spatial pattern of recorded gaze locations corresponded with the pattern of calibration targets being presented. After successful calibration, manual validation using the same set of images started. If calibration and/or validation failed, the procedure was repeated until both calibration and validation were acceptable or the procedure had to be aborted. The mean validation error was $M = .80^{\circ}$ ($SD = .27$). If acceptable calibration and validation were obtained, the action demonstration video was presented and participants' eye movements were recorded. After the action demonstration video was finished, infants and their caregivers were escorted to the waiting room.

2.3.3. Delay and imitation phase

During the 30-min delay infants and caregivers stayed in the waiting room. The infant participated in no additional tasks and was free to play. After the delay, the infant and the caregiver were again escorted to the laboratory room. The procedure was the same as in the baseline phase. Infants' playing behavior was videotaped again by two cameras.

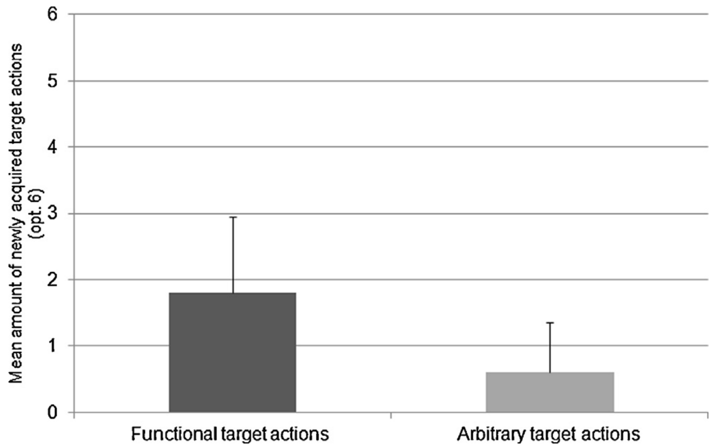

Fig. 1. Mean amount of newly acquired functional and arbitrary target actions. *Note*. Error bars indicate standard deviations.

2.4. Data coding

2.4.1. Coding of target action performance

Infants' videotaped performance of target actions was scored by a naïve rater according to operational definitions listed in Table 1. One third of the videotapes were additionally scored by a second rater. Both raters were blind to the hypotheses of the study. Inter-rater reliability was high, $\kappa = .81$ ($p < .001$), and rater disagreement was resolved by forced consent.

2.4.2. Coding of eye tracking data

The action demonstration video was segmented into pre-defined parts, so-called Periods of Interest (POIs), to enable the assessment of infants' gaze behavior during different kinds of scenes. Two kinds of POIs were defined: Talking POIs and Target Action POIs. During Talking POIs the video showed the model with one of the test objects in front of him on the table, talking to the infant and establishing a social-communicative context by saying "Look! I will show you something", before the first demonstration of an item, or "Look! I will show it again", before every consecutive demonstration. During Target Action POIs the video showed the model demonstrating the functional and arbitrary target actions (Functional Target Action POIs and Arbitrary Target Action POIs). Talking POIs were defined for each demonstration of each item (6 items × 3 demonstrations), and Target Action POIs were defined for each demonstration of each target action (6 items × 3 demonstrations × 2 target actions).

Relevant parts of the screen, such as the model's face and the area where the target actions took place, were defined as Areas of Interest (AOIs). Both the Face AOI and the Action AOI were defined for each POI separately. The Face AOI contained the model's face during both Talking POIs and Target Action POIs. The Action AOI contained the object in front of the model during Talking POIs and both the object and the model's acting hand during Target Action POIs. All AOIs were rectangular, defined by pixel coordinates of the extreme positions of the AOIs' content within a certain POI. To obtain these coordinates, we converted the action demonstration video into JPG-files using the software DVD Video Soft Free Studio and measured the extreme positions of the areas using the image editing software Gimp.

3. Results

3.1. Infants' deferred imitation of target actions

3.1.1. Variables and preliminary analysis

After the performance of each target action in the baseline resp. imitation phase had been coded, the amount of newly acquired target actions, i.e., target actions performed in the imitation phase but not in the baseline phase, was computed. Deferred imitation was inferred if the amount of newly acquired target actions was greater than zero, indicating a memory effect. The effect of gender on the amount of newly acquired target actions was analyzed by a one-way ANOVA, which found no effect ($F(1, 18) = .36$, $p = .556$, $\eta^2 = .02$), thus gender will not be considered in further analyzes.

3.1.2. Deferred imitation of functional and arbitrary actions

Mean amounts of newly acquired functional and arbitrary target actions are given in Fig. 1.

Both the total amount of newly acquired target actions and the amounts of newly acquired functional resp. arbitrary target actions were greater than zero ($t = 7.32$, one-tailed $p < .001$, Cohen's $r = .76$ and $t = 6.99$, one-tailed $p < .001$, $d = 2.21$, Cohen's $r = .74$ resp. $t = 3.56$, one-tailed $p = .001$, $d = 1.13$, Cohen's $r = .49$). This shows a memory effect for both kinds of target action. Descriptive statistics show that ten out of twelve target actions were acquired by some infants. Both target actions that were not acquired were arbitrary (items ship and frog, see Table 1).

To test the hypothesis that infants would imitate more functional than arbitrary target actions, the amounts of newly acquired functional vs. arbitrary target actions were compared by a paired t test. Infants acquired significantly more functional than arbitrary target actions from the demonstration, $t = 4.19$, $p < .001$, Cohen's $r = .69$. Descriptive statistics additionally demonstrate that the functional target action was acquired more frequently than the arbitrary one in each item.

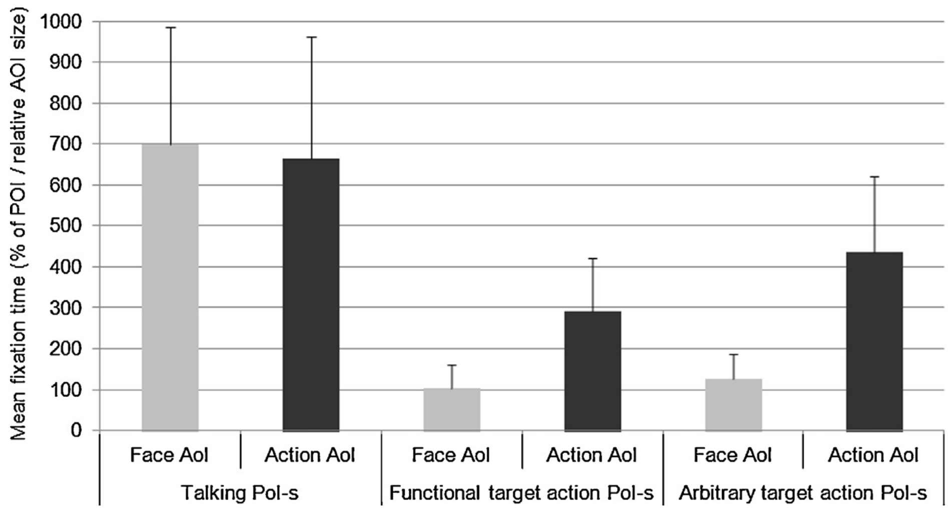

Fig. 2. Mean fixation times to the face vs. action AOI during talking POIs, functional target action POIs and arbitrary target action POIs. *Note*. Fixation times were corrected using the formula (% of POI/relative AOI size). Error bars indicate standard deviations.

Table 2
T-Test statistics comparing fixation times to the action AOI during functional vs. arbitrary target action POIs in each item.

Item	*t*	*p*	Cohen's *r*
Ship	−3.16	.005	.59
Cow	9.23	<.001	.90
Mouse	−7.14	<.001	.85
Frog	6.23	.001	.82
Drum	−0.32	.760	.07
Duck	5.64	<.001	.79

3.2. Eye tracking data

3.2.1. Variables and preliminary analysis

All variables were computed based on the Fixation Report obtained from the Eye Link Data Viewer. For each POI in each item we computed the fixation time to the Face AOI and to the Action AOI, the amount of fixations in the Face AOI and in the Action AOI, as well as the amount of saccades between the Face AOI and the Action AOI. To compensate for differences in POI duration, we calculated all variables as the percentage of total POI length. Additionally, to compensate for differences in AOI sizes, the percentage values of fixation times and amounts of fixations (but not of amounts of saccades) were divided by the relative size of the corresponding AOI. All analyzes were conducted on these corrected variables, but for simplicity's sake we will refer to fixation times, amounts of fixations and amounts of saccades.

A preliminary analysis of correlations between corresponding fixation times and amounts of fixations showed that these variables were highly correlated throughout all POIs and AOIs ($r_{min.}$ = .63, $r_{max.}$ = .94; p_{min} < .001, p_{max} = .003). Thus, only fixation times were included in the main analyzes. Then, a series of one-way ANOVAs was used to test the effect of participants' gender on the gaze variables. No significant gender effect was found (highest $F(1, 18) = 1.94$, $p = .181$, $\eta^2 = .10$), thus this factor will not be considered further.

3.2.2. Infants' fixation times during target action demonstration

Mean fixation times to the Face AOI and the Action AOI during Talking POIs, as well as during Functional and Arbitrary Target Action POIs are given in Fig. 2.

Fixation times were analyzed in a RM ANOVA including the within-subjects factors AOI (Face, Action) as well as POI (Talking, Functional Target Action, Arbitrary Target Action). Both main effects as well as the interaction were significant. The effect of AOI, $F(1, 19) = 18.06$, $p < .001$, $\eta_p^2 = .49$, shows that overall fixation times to the Action AOI were longer than fixation times to the Face AOI. However, descriptive statistics show that this was not the case in every POI of every item. The effect of POI, $F(1.18, 22.38) = 133.83$, $p < .001$, $\eta_p^2 = .88$, was further analyzed by paired comparisons which showed that all differences were significant: Fixation times were longer during Talking POIs than during both Functional and Arbitrary Target Action POIs ($SE = 39.72$, $p < .001$ and $SE = 35.12$, $p < .001$, respectively), and they were longer during Arbitrary than during Functional Target Action POIs, $SE = 13.74$, $p < .001$. Descriptive statistics hereby show a variation across items. Additionally, an AOI × POI interaction, $F(1.21, 22.94) = 15.24$, $p < .001$, $\eta_p^2 = .45$, was found. The interaction was further analyzed by paired *t* tests and will be described in the following sections.

3.2.2.1. Fixation times to the Face AOI. Fixation times to the Face AOI were longer during Talking POIs than during both Functional and Arbitrary Target Action POIs ($t = 10.65$, $p < .001$, Cohen's $r = .93$ and $t = 10.41$, $p < .001$, Cohen's $r = .92$, respectively) and did not differ between Functional and Arbitrary Target Action POIs ($t = -2.00$, $p = .060$, Cohen's $r = .42$). This shows that infants looked longer to the model's face while he was talking than while he was demonstrating the target actions.

3.2.2.2. Fixation times to the Action AOI. Fixation times to the Action AOI were longer during Talking POIs than during both Functional and Arbitrary Target Action POIs ($t = 7.03$, $p < .001$, Cohen's $r = .85$ and $t = 4.77$, $p < .001$, Cohen's $r = .74$, respectively), and they were longer during Arbitrary Target Action POIs than during Functional Target Action POIs ($t = 5.66$, $p < .001$, Cohen's $r = .79$). Since this last difference concerns one of the main hypotheses of the present study, namely that selective attention does not account for selective imitation, we examined it in more detail. Item-level *t*-test statistics on fixation times to the Action AOI during Functional vs. Arbitrary Target Action POIs are given in Table 2.

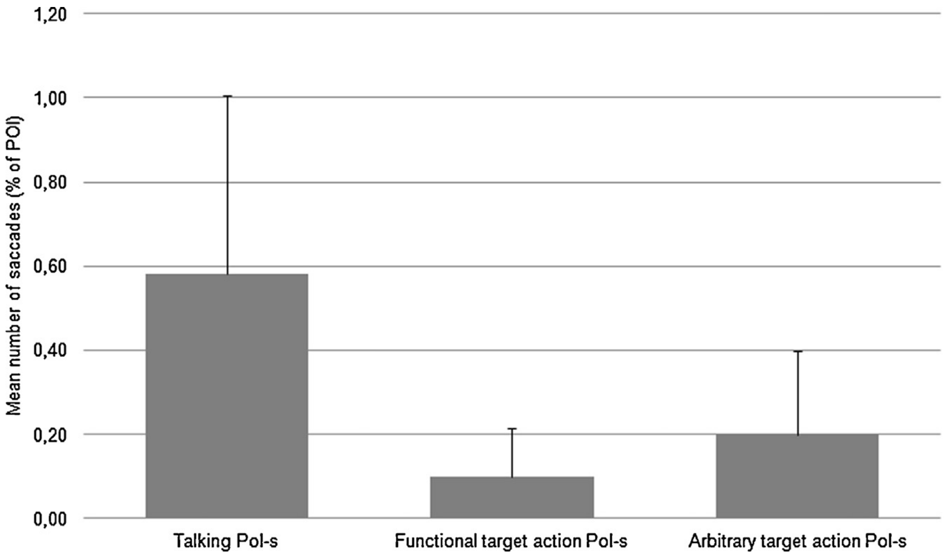

Fig. 3. Mean number of saccades between face AOI and action AOI during talking POIs, functional target action POIs and arbitrary target action POIs. *Note.* The number of saccades was corrected for the length of each POI (% of POI). Error bars indicate standard deviations.

These *t* tests showed that although five out of six differences were significant, the direction of the differences varied. For the three items "cow", "frog" and "duck", fixation times to the Action AOI were longer during Arbitrary than during Functional Target Action POIs, but for the items "ship" and "mouse" the opposite was found.

3.2.2.3. Differences between fixation times to the two AOIs. Fixation times to the Action vs. Face AOI did not differ during Talking POIs, $t = .45$, $p = .659$, Cohen's $r = .10$. Contrary to this, fixation times to the Action AOI were longer than to the Face AOI during both Functional and Arbitrary Target Action POIs, $t = -6.66$, $p < .001$, Cohen's $r = .84$ and $t = -8.19$, $p < .001$, Cohen's $r = .88$, respectively. This shows that infants looked as long to the model's face as to the object while the model was talking, but they looked longer to the target action than to the model's face while target actions were demonstrated.

3.2.3. Infants' saccades between the model's face and the object

In addition, the amount of saccades between the Face AOI and the Action AOI during the three different POIs was analyzed. Means amounts of saccades are given in Fig. 3.

The effect of POI on the amount of saccades was analyzed by a RM ANOVA in which a main effect of POI, $F(1.19, 22.55) = 22.23$, $p < .001$, $\eta_p^2 = .54$, was found. Planned comparisons revealed that all differences among the POIs were significant: The amount of saccades was larger during Talking POIs than during both Arbitrary ($SE = .09$, $p = .001$) and Functional Target Action POIs ($SE = .09$, $p < .001$), and it was larger during Arbitrary Target Action POIs than during Functional Target Action POIs ($SE = .03$, $p = .015$). Descriptive statistics show that the amount of saccades was highest during Talking POIs in every item, indicating that infants shifted their gaze between the model's face and the object more frequently while the model was talking. However, the direction of the difference between the two Target Action POIs shows a variation across items, suggesting that infants' gaze shifts between the model's face and the object during the demonstration of target action were influenced by the actions' perceptual characteristics rather than functionality (cf. Elsner et al., 2013).

3.3. Relations between infants' gaze and deferred imitation

3.3.1. Overall relations between infants' gaze and deferred imitation

As presented above, the effect of functionality on deferred imitation performance was consistent, as the functional target action was acquired more frequently than the arbitrary one in each item. Contrary to this, the effect of functionality on infants' gaze varied across items. These contrasting findings indicate that preferential imitation of functional target actions cannot rely on selective visual attention toward these target actions. In order to support this assumption, we calculated correlation coefficients between gaze and deferred imitation variables (fixation times to the Face AOI and the Action AOI and amounts of saccades during different POIs, as well as amounts of newly acquired functional and arbitrary target actions).

The amount of newly acquired functional target actions did not correlate with any of the gaze variables (highest $r = .29$, lowest $p = .159$). Contrary to this, the amount of newly acquired arbitrary target actions correlated with fixation times to the Face AOI during Talking POIs, $r = .52$, $p = .019$, as well as with fixation times to the Action AOI during both Functional and Arbitrary Target Action POIs ($r = .60$, $p = .005$ and $r = .54$, $p = .013$, respectively). This shows that infants' gaze behavior was not related to their overall deferred imitation performance, but only to the acquisition of new arbitrary target actions.

3.3.2. Interindividual differences in gaze and deferred imitation

The analysis of correlations suggested that infants' gaze toward the target actions was related to the acquisition of arbitrary target actions. To further analyze this relationship, we distinguished two subsamples of infants in a post hoc analysis: one subsample consisted of infants who acquired only functional target actions from the model (*selective imitators*, $n = 8$), the other subsample consisted of infants who acquired both functional and arbitrary target actions (*exact imitators*,[2] $n = 9$). A third subsample, consisting of three infants who did not acquire any functional target actions from the model, was not included in this analysis due to small sample size.

For the purposes of the comparison between the two subsamples, two new variables were computed: the total amount of on-screen fixations as a general measure of infants' attention to the video, and the mean length of fixations during the total video presentation, which was found to be related to information processing and memory performance in previous studies (Colombo, Mitchell, & Horowitz, 1988; Kirkorian, 2007). Gaze behavior and target action performance of selective imitators vs. exact imitators were compared by a series of one-way ANOVAs. The test statistics are given in Table 3.

[2] Note that infants in the subsample labeled exact imitators still imitated significantly more functional than arbitrary target actions, i.e., their imitation was not perfectly exact, merely more exact than the imitation of the subsample labeled selective imitators.

Table 3
Test statistics of the one-way ANOVAs comparing behavioral and gaze variables of selective imitators vs. exact imitators.

Variable type	Variable	$M_{selective}$	M_{exact}	$F(1, 15)$	p	η^2
Target action performance	Number of newly acquired functional target actions	2.00	2.22	.23	.637	.02
	Number of functional target actions performed in the baseline	1.50	1.33	.29	.596	.02
	Number of arbitrary target actions performed in the baseline	.25	.22	.02	.901	.001
General gaze characteristics	Number of on-screen fixations during the total video demonstration	302.75	347.56	.84	.374	.05
	Mean length of fixations during the total video demonstration	14.32	15.23	.57	.461	.04
Gaze during Talking POIs	Mean fixation time to the Face AOI during Talking POIs	502.93	871.40	9.78	.007*	.39*
	Mean fixation time to the Action AOI during Talking POIs	510.67	753.19	2.90	.109	.16*
	Mean amount of saccades between the Face AOI and the Action AOI during Talking POIs	.35	.78	7.50	.015*	.33*
Gaze during Target Action POIs	Mean fixation time to the Face AOI during Functional Target Action POIs	82.96	112.60	1.25	.281	.08
	Mean fixation time to the Action AOI during Functional Target Action POIs	186.76	368.64	13.41	.002*	.47*
	Mean amount of saccades between the Face AOI and the Action AOI during Functional Target Action POIs	.07	.12	.75	.401	.05
	Mean fixation time to the Face AOI during Arbitrary Target Action POIs	102.06	143.29	1.73	.208	.10
	Mean fixation time to the Action AOI during Arbitrary Target Action POIs	295.76	551.23	13.20	.002*	.47*
	Mean amount of saccades between the Face AOI and the Action AOI during Arbitrary Target Action POIs	.12	.27	3.27	.090	.18*

Note. $M_{selective}$ refers to group means of selective imitators and M_{exact} refers to group means of exact imitators. Significant differences and large effect sizes ($\eta^2 > .14$) are marked with an asterisk.

On the one hand, no significant differences between these two subsamples were found in behavioral scores, indicating that exact imitators did not imitate more functional target actions, nor did they perform more target actions in the baseline phase than selective imitators. On the other hand, several group differences were observed for the gaze variables. Although the two subsamples did not differ in the amount of on-screen fixations and the mean length of fixations, a specific pattern of gaze behavior was observed in the subsample of exact imitators: During Talking POIs, exact imitators had longer fixation times to the Face AOI than selective imitators, and they had also more saccades between the Face AOI and the Action AOI. During Target Action POIs, exact imitators had longer fixation times to the Action AOI than selective imitators, while fixation times to the Face AOI, as well as the amount of saccades between the two AOIs did not differ. This was true for both Functional and Arbitrary Target Action POIs.

4. Discussion

The present study analyzed 18-month-olds' gaze behavior while infants were observing a demonstration of functional and arbitrary target actions. Additionally, infants' deferred imitation of these actions was assessed. Besides aiming to replicate previous findings on 18-month-olds' deferred imitation (Kolling et al., 2010) and neither completely selective, nor completely exact imitation (Nielsen, 2006; Óturai et al., 2012; Tennie et al., 2006), we expected no overall relation between the patterns of infants' gaze during action demonstration and their target action imitation (Esseily, 2012; Kirkorian, 2012; Kolling et al., 2013). Furthermore, in a post hoc analysis we analyzed finer-grained relations between gaze and deferred imitation by testing interindividual differences in two subsamples, namely selective imitators vs. exact imitators. The findings concerning infants' deferred imitation, infants' gaze behavior during action demonstration, overall relations between gaze behavior and imitation, and the post hoc analysis of interindividual differences will be discussed consecutively, before general conclusions will be drawn.

4.1. Infants' deferred imitation

Infants in the present study engaged in deferred imitation, which indicates a memory effect and replicates former findings (Barr et al., 1996; Barr & Hayne, 2000; Kolling et al., 2010; Óturai et al., 2012). In addition, this finding adds to a growing body of evidence showing that infants in their second year of life are able to imitate target actions that were demonstrated via video (Barr, Muentener, & Garcia, 2007; Kolling et al., 2013).

Furthermore, although 18-month-olds in the present study showed a memory effect for both action kinds, they imitated more functional than arbitrary target actions, which is also consistent with previous findings (Óturai et al., 2012). This finding demonstrates that infants distinguished between functional and arbitrary target actions across a series of different items and supports the theory that although at the age of 18 months social motivations become important for imitative processes, infants are still driven by a cognitive motivation to learn about objects and their functions (cf. Uzgiris, 1981). However, the findings of the present study do not allow any conclusion about whether infants were aware of the functionality of functional actions or whether lower-level action characteristics accounted for the higher imitation rate of functional than of arbitrary actions. Since functional actions are defined by their stronger connection to the objects, they might be inherently easier to encode and retrieve than arbitrary actions that are only loosely (and arbitrarily) connected to the objects.

4.2. Infants' gaze behavior during target action demonstration

Fixation times to the Face AOI and the Action AOI during Talking POIs, Functional Target Action POIs and Arbitrary Target Action POIs were assessed in order to investigate infants' visual attention toward different components of target action demonstration. The results showed that while the model was talking to the infants and establishing a social-communicative context (Talking POIs), infants attended to both the model's face and the object that the model was referring to. However, they looked significantly longer to the area of the target action than to the model's face while target actions were demonstrated (Target Action POIs), which shows an adequate gaze shift toward the area displaying new information. Overall fixation times to the Action AOI were longer during Arbitrary than during Functional Target Action POIs, which is in contrast with previous results reporting nonselective looking times to functional vs. arbitrary target actions (Kolling et al., 2013). However, an item-level analysis revealed a substantial variation among items, showing that infants looked longer to the arbitrary target action in some items, but they looked longer to the functional action in others.

An analysis of infants' saccades between the Face AOI and the Action AOI adds to a more detailed picture of infants' gaze patterns. Our results showed that the number of saccades was larger during Arbitrary than during Functional Target Action POIs, which might be an indicator of infants looking for an explanation for the arbitrary actions in the model's face (cf. Vivanti et al., 2008). During Talking POIs infants showed even more saccades between the Face AOI and the Action AOI than during both of the Target Action POIs. This suggests that during the time periods when the videotaped model was communicating, infants were engaging in a joint-attention-like episode with him. Neither of these differences was found in 12-month-olds (Kolling et al., 2013), which supports our interpretation that the increased number of saccades between the Face AOI and the Action AOI during Arbitrary Target Action POIs and Talking POIs indicate infants' search for social-communicative cues about the ongoing action, respectively infants' engagement in the social-communicative context of the task.

4.3. Overall relations between gaze behavior and deferred imitation

Infants did not preferentially look at one kind of target action during action demonstration, as the difference between fixation times to the Action AOI during Functional vs. Arbitrary Target Action POIs was not consistent and can be accounted for by a variation across items. Infants' deferred imitation, however, was selective, as the functional target action was imitated more frequently than the arbitrary one in each item. This contrast between non-selective gaze behavior and selective imitation strengthens the position that selective imitation cannot be explained by selective visual attention (Esseily, 2012; Kirkorian, 2012; Kolling et al., 2013). Additional evidence is provided by the analysis of correlations between gaze behavior and imitation behavior, which found no clear correspondence between looking times to and imitation rate of target actions.

4.4. Interindividual differences in gaze and deferred imitation

Despite the lack of overall correspondence between gaze behavior toward and imitation of target actions, significant correlations showed that the longer infants looked to the model's face while he was talking and to the action area while target actions were demonstrated, the more arbitrary (but not functional) target actions they imitated. This correlational finding was complemented by a post hoc analysis of two subsamples of infants, namely selective imitators and exact imitators. Compared to selective imitators, exact imitators looked longer to the model's face while the model was talking, and they looked longer to both functional and arbitrary target actions while those were demonstrated. Additionally, while the model was talking, exact imitators had more saccades between the model's face and the object than selective imitators. Importantly, the two subsamples did not differ in terms of their overall gaze behavior such as mean length of fixations and the amount of fixations during the whole action demonstration, nor did they differ in their behavioral baseline performance or the number of functional target actions they acquired during demonstration. This pattern of results suggests that exact imitators were more involved in the social-communicative context of this imitation task, and they also seemed to follow the model's cues about the "new and relevant information" (Csibra & Gergely, 2006), i.e., the target actions, more efficiently than selective imitators.

Interpreting these findings in the framework suggested by the theory of natural pedagogy (Csibra & Gergely, 2006; Csibra & Gergely, 2009), exact imitators' stronger sensitivity to the model's social-communicative cues was shown by their longer fixation times to the Face AOI during Talking POIs. At the same time, their larger number of saccades between the model's face and the object suggested that they participated more actively than selective imitators in this joint-attention-like episode with the model. This active involvement enabled exact imitators to follow the model's cues about the target actions to be demonstrated more closely, as evidenced by longer fixation times to the Action AOI during the demonstration of both kinds of target action. This means that exact imitators had a better chance to encode the target actions than selective imitators. This advantage, however, was not reflected in their overall deferred imitation performance, but only in the amount of newly acquired arbitrary target actions. This is consistent with the idea that sensitivity to and involvement in the social-communicative context of imitation facilitates more exact imitation (e.g., Gergely, 2003), i.e., imitation of not only functional, but also arbitrary target actions.

Although the present findings are consistent with a pedagogical explanation, exact imitators' increased attention to the model is no direct evidence of these infants' sensitivity to the model's social-communicative cues. The same gaze pattern might result from other aspects of infants' social orientation, such as the motivation to be like the model (see Over & Carpenter, 2012a, 2012b; Zmyj, Aschersleben, Prinz, & Daum, 2012).

5. Conclusions

The results of the present study replicated a series of former findings demonstrating that 18-month-old infants are able to imitate a number of target actions following a delay (Kolling et al., 2010), even if the target actions were demonstrated via video (Barr et al., 2007). Additionally, our findings also add to a growing body of evidence showing that 18-month-olds do not imitate entirely selectively as younger infants do, but neither do they imitate completely exactly as two-year-olds do (Nielsen, 2006; Tennie et al., 2006).

Analyzes of the relations between gaze behavior and deferred imitation for the total sample of 18-month-olds yielded no consistent correspondence between visual attention and imitation performance, thus suggesting that selective imitation of functional as opposed to arbitrary target actions should be explained by other processes than selective visual attention toward functional actions (Kolling et al., 2013). Although this finding does not provide an exhaustive explanation of selective imitation, excluding the selective attention hypothesis is essential for theories proposing higher cognitive processes as an explanation for selective imitation.

Finally, the post hoc analysis of gaze and imitation patterns of selective imitators vs. exact imitators suggested that infants' imitative behavior is affected by the social-communicative context of the imitation task. More importantly, while previous studies established this effect by varying the degree of social availability provided by the model (Király, 2009; Nielsen, 2006; Nielsen et al., 2008), our findings are the first to indicate that infants' actual involvement in the social-communicative context of the task also affects what they learn from target action demonstration. Infants who showed increased attention to the model's social-communicative cues and also followed these cues more efficiently acquired not only functional, but also arbitrary target actions from the model. Infants who showed less sensitivity to the model's cues and looked less to the target actions were also able to acquire new target actions from the demonstration and thus engage in deferred imitation. These infants, however, acquired only functional target actions, which are more closely linked to the action-related objects than arbitrary ones. Nevertheless, due to the small sample size, these findings have to be interpreted with caution. The question whether exact imitators' and selective imitators' different gaze patterns relied on situational factors or whether they reflect stable processes remains open for future research.

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