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Understanding of Iconic Gestures in Chimpanzees
and Four-Year-Old Human Children

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“... the question of how language is related to the world.”

Merlin Donald, *Origins of the Modern Mind*

ABSTRACT

Iconic gestures, i.e. hand movements or body postures that resemble their referents, have been highlighted as an important means of communication in the evolution of language, as they enable flexible communication without prior conventionalization (Armstrong & Wilcox, 2007; Tomasello, 2008). However, very little is known about their evolutionary origins. Some observational studies report production and understanding of iconic gestures in great apes (Tanner & Byrne, 1996; Pika & Mitani, 2004, 2006) but it is unclear, if these gestures are really understood by means of being iconic. On the other hand, human children produce and understand iconic gestures from around their second birthday (Behne, Carpenter & Tomasello, 2010; Namy, 2008). However, it is unclear whether human children treat iconic gestures differently from arbitrary gestures, when the gesture is informative. To investigate these questions, we compared chimpanzees' (*Pan troglodytes*) and four-year-old human children's (*Homo sapiens*) ability to use iconic and arbitrary gestures as a cue in a decision making task.

Eleven chimpanzees and twenty-four four-year-old human children participated in the study. In a within-subject design, two conditions (ICONIC and ARBITRARY) were administered in a counterbalanced order. A gesture was used as a cue for the subject to decide between two locations, of which only one yielded a reward. The relationship between the gesture and the location was either iconic or arbitrary, depending on the presence or absence of an apparatus at each location. The actions used as iconic gestures (e.g. 'pulling down a rope' or 'pushing in a lever') were derived from a mutual activity between the subject and the experimenter (E) at the apparatus. In the ARBITRARY condition, no such relationship was in place. The general setup, the gestures and the apparatus were identical for both species. We coded whether the subject's choice matched the side indicated by E. Each individual received 24 trials per condition. Additionally, chimpanzees received more trials to investigate their performance over time.

We found, that subjects performed better if they received the ICONIC condition first. This suggests that iconic gestures help to establish a communicative setting. Furthermore, children performed significantly better in the ICONIC condition, compared to their own performance in the ARBITRARY condition and to chimpanzees' overall performance. This suggests that children, but not

chimpanzees, are able to use iconic, but not arbitrary cues, to guide their decision. An analysis of chimpanzees' performance over time revealed that they reach a certain level of performance faster when provided with iconic gestures as opposed to arbitrary gestures.

These findings suggest that children and chimpanzees distinguish between iconic and arbitrary gestures. However, only human children are able to immediately understand iconic gestures as communicative.

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1 INTRODUCTION

1.1 GENERAL INTRODUCTION

This section outlines the theoretical background to the empirical study. Firstly, I discuss the evolutionary background for the study of iconic gestures (or pantomime). Next, I give a short review of gestural communication in human children and non-human great apes (hereafter apes). Subsequently, I discuss the cognitive mechanisms relevant to the understanding of iconic gestures with regard to the cognitive abilities of human children and great apes. In the final section, I introduce the empirical study and discuss the results.

1.1.1 *Gestural Theories of Language Evolution*

C. S. Peirce's semiotic theory (1932) distinguishes between three different relations between signs and objects: symbolic, indexical and iconic. A symbol (or token) is related to its object only as a consequence of an abstract and arbitrary mental association. The use of such a symbol is therefore conventional. In contrast, an index has a direct (Peirce: compulsive) relationship to its object. The mind recognizes the relationship and causal structure between sign and object. An icon stands for something because it resembles its denoted object.

From a cognitive perspective, symbols are the most demanding because the relationship between sign and object is purely arbitrary. Icons also rely on a cognitive process to recognize relationships. Indices, on the other hand, need no intermediate computational stage since they are causally connected to the objects they denote.

If we categorize human and animal communication with reference to Peirce, human language clearly operates with symbols. However, animal communication does not because the relationship between animal signals and the objects they denote is not arbitrary but shaped by natural selection or a process of ritualization (Wheeler & Fischer, 2012). Furthermore, animal communication is not iconic and so one could call animal signals indexical, as they are naturally (biologically) linked to the things they denote (Fitch, 2010).

So, from an evolutionary point of view, the following question arises: How did the transition from indexical to symbolic communication occur? It is reasonable to assume a transitional period between animal and human communication in which the socio-cognitive and socio-motivational architecture supporting symbolic communication could evolve (Donald, 1991). Being cognitively less demanding than symbolic signs, iconic signs might have played an important role in this transition. For cognitive and comparative reasons, gestures are a suitable candidate for communication during this transitional period. Several theories on the gestural origins of language have now been proposed (Armstrong & Wilcox, 2007; Corballis, 2011; Tomasello, 2008 and partly also Donald, 1991)

Drawing the phylogeny – ontogeny analogy, these theories are supported by empirical studies of the ontogeny of human communication. Children communicate via gestures in a sophisticated manner before they do so linguistically (e.g. Tomasello, 2008; see section 1.1.2 for more details) and while language requires a long period of learning, some forms of gestures emerge spontaneously (Matthews, Behne, Lieven, & Tomasello, 2012).

Further evidence for a gestural theory of language evolution comes from comparative studies with great apes. Chimpanzees show very little ability when it comes to acquiring new vocal signals (Hayes & Hayes, 1951). On the other hand, they acquire new manual signals, such as hand signs from American Sign Language (ASL), with relative ease (Gardner & Gardner, 1969). Furthermore, apes direct gestures to conspecific in an intentional and flexible way, while their vocalizations seem to be restricted in terms of intentional control, flexibility and adjustment for audience (Tomasello & Zuberbühler, 2002; but see Crockford, Wittig, Mundry, & Zuberbühler, 2012)

Gestural communication takes place in evolutionary less urgent contexts such as play, nursing and grooming. There is less selection against variability in the signal in these contexts because there are no lethal consequences when communication fails. This might account for the greater variation and flexibility exhibited in ape gestures (Call & Tomasello, 2007; Tomasello, 2008).

Iconic gestures play an important role in the gestural theories of language evolution as they provide a means to communicate about absent entities in a ‘natural’ way. They could be called ‘naturally meaningful’, as they enable communication without a prior process of evolutionary or ontogenetic ritualization and without depending on communicative conventions. All that is necessary is to

depict and understand the resemblance between sign and object. Tomasello (2008) imagines them as a precursor to content words and sees their roots in the intention-movement gestures (see section 1.1.2 for details) of apes. However, little is known about the circumstances in which children and apes can use this kind of ‘natural’ information that is contained in an iconic gesture. The study presented in this thesis aims to address this question.

1.1.2 Gestural Communication in Human Children

Before they are able to express themselves linguistically, human infants communicate with others gesturally. However, human gestural communication is not uniform and several different types of gestures can be identified: Speech accompanying gestures, conventional gestures, ritualized gestures, deictic gestures and iconic gestures.

Deictic and iconic gestures are referential (mostly triadic), complete communicative acts and do not depend on social experience with that particular gesture. Furthermore, they seem to be culturally universal. As noted in section 1.1.1 this makes them interesting in an evolutionary scenario. On the other hand, speech accompanying gestures only have a supportive role in spoken language and are not complete communicative acts in themselves (Tomasello, 2008). Conventional gestures, such as culture specific gestures for greeting or insulting share essential features with conventional linguistic communication. They are socially learned symbolic conventions and are only understood within a specific cultural context (Tomasello, Carpenter, & Liszkowski, 2007). Ritualized gestures, such as raising the arms in order to be lifted up, depend on repeated interactions of the same type and are mainly dyadic (The process of ontogenetic ritualization will be described in detail in section 1.2). In the remaining section, I will briefly discuss the pointing behavior of human children, as the most important form of deictic gesture, and then focus on iconic gestures.

Deictic gestures usually serve to spatially direct others’ attention to some aspect of the perceptual environment, with pointing as the prototypical example (Tomasello, 2008). Due to its fundamental role in enabling joint attention, pointing plays an important role in early language acquisition (e.g. Bruner, 1985, Tomasello, 1988; Tomasello, et al., 2007). Human children reliably produce pointing gestures before they start to produce iconic gestures. Around their first birthday they already point for others in many different situations. Furthermore, they do so without training (Matthews, et al., 2012). In terms of production, they use this gesture to request objects, share their interest with

others (Behne, Liszkowski, Carpenter, & Tomasello, 2012), inform ignorant others about the location of hidden objects (Liszkowski, Carpenter, Striano, & Tomasello, 2006) and even refer to absent entities (Liszkowski, Schäfer, Carpenter, & Tomasello, 2009). They also understand informative pointing around the same age (Behne, et al., 2012). According to Tomasello (2008) these early communicative abilities allude to a rich socio-cognitive infrastructure, including understanding of cooperative communicative intentions and tracking of common ground (see section 1.2 for more details).

Even though pointing enables communication about absent entities, for example by pointing to locations where objects usually are or actions are usually performed, it is clearly limited. The point merely denotes the referent but gives no information about the content the communicator wants to convey. Iconic gestures enable a much wider range of communication about absent entities. They can be described as a hand and/or body position that resembles a perceptually absent entity. In using such a gesture a communicator induces a recipient to imagine the referent or an aspect of the referential situation (Namy, 2008; Tomasello, 2008). When referring to actions, iconic gestures usually depict functionally ineffective versions of the action. For example:

Example: You are sitting in a restaurant with an unlit candle on your table. The next time the waiter looks over to you from the other side of the room you look back at him, lift your hand, make a fist, move your thumb up and down and point to the candle. The waiter nods and soon after he comes over with a lighter and lights your candle.

The waiter recognized your gesture and he was led to imagine you lighting a lighter. In combination with the point to the candle he inferred your reasons for using this gesture.

Recognizing iconic relationships between signs and their referents has been viewed as a steppingstone towards the acquisition of arbitrary symbols (Piaget, 1951). This view has been challenged, since there seems to be no temporal advantage for the acquisition of iconic over arbitrary signs in human ontogeny (Namy, Campbell, & Tomasello, 2004; see also Tomasello, 2008 and Liszkowski, 2010 for reviews, but see Imai, Kita, Nagumo, & Okada, 2008 for supporting function of sound symbolism). The frequency of iconic gestures also declines with increasing linguistic abilities (Tomasello, 2008).

Human children start to produce iconic gestures in the months after their first birthday, along with other conventionalized gestures and their first words. However, they do so much less frequently than pointing (Tomasello, 2008). Additionally, it is not clear to what extent young children are aware of the iconicity in their own gestures, so it is conceivable that children do not treat iconic and conventional gestures differently at this early age. Namy (2008) showed that children younger than 26 months failed to recognize iconic gestures in a communicative setup. In this study she asked children to select an object based on a gesture that was derived from an action previously performed on the object. Together, these results suggest that iconicity does not play a major role in symbol learning at the onset of symbolic development.

However, iconic gestures are a useful means of communication when there is no shared language (or code) to make oneself understood (e.g. when tourists are unfamiliar to the language in a foreign country). Furthermore, they might help children to communicate in situation when the message they want to convey exceeds their linguistic abilities. Behne, Carpenter and Tomasello (2010) provide evidence for this in a study showing that 27-month old children creatively used iconic gestures to instruct a naïve puppet on how to operate an apparatus. In this study, verbal descriptions were most likely beyond young children's linguistic ability.

In summary: young children communicate with others gesturally based on a rich socio-cognitive infrastructure. Even though iconic gestures do not seem to play a major role in early communication and symbolic development, children creatively produce and understand them in communicative situations from an early age. However, it is unclear, whether human children treat iconic gestures differently, compared with arbitrary gestures. Namy et al. (2004) showed that 18-month-olds mapped iconic and arbitrary gestures equally well onto a certain object. Whereas 26-month-olds only mapped iconic gestures onto objects, four-year-olds mapped both kinds of gestures. However, in this study the gestures were explicitly paired with a certain object. It is an open question, whether children differentiate between iconic and arbitrary gestures, when the communicative function has to be inferred from the context. It might be that human children have a general understanding of when someone is acting with communicative intent, which enables them to infer the meaning of whatever communicative means based on the context.

1.1.3 Gestural Communication in Great Apes

Great ape gestural communication spans across three different modalities: visual, auditory and tactile, with the proportion of each modality varying across species. Gestural communication is known to be intentional, flexible and adjusted to the attentional state of the recipient (Tomasello & Call, 2007; Hobaiter & Byrne, 2011). Intentional communication is defined as the flexible adjustment of a signal with regard to a communicative goal (Call & Tomasello, 2007; Liebal, Müller, & Pika, 2007). This implies that the communicator, and not an external stimulus, controls the production of a signal depending on her communicative goal. In an experimental study, Leavens, Russell and Hopkins (2005) showed that chimpanzees persisted to beg and elaborated their begging gesture when they received a less valuable reward than the one that was initially presented. This suggests that they intended to get the full reward and used their gestures as a means to this end. Furthermore, gestures are repeated or combined with other gestures of the same or a different modality, in order to pursue the communicative goal (Hobaiter & Byrne, 2011; Liebal, Call, & Tomasello, 2004). Evidence that the same gesture might be used for different goals and different gestures might be used to pursue the same goal demonstrates flexibility (Call & Tomasello, 2007). For example, a chimpanzee might use a gesture that involves reaching out with an outstretched arm towards a conspecific in order to beg for food in a feeding context but also to request help in an agonistic context. In addition to flexibility, apes show that they are able to adjust their gestures to the attentional state of the audience. Visual gestures are mainly used when the recipient is facing towards an individual, whereas tactile gestures are used irrespective of the body orientation of the recipient. Auditory gestures with a visual component are also preferentially used when the recipient is attending (Tomasello & Call, 2007).

The classical account of ape gestural communication proposed by Tomasello and colleagues (Tomasello, George, Kruger, Farrar, & Evans, 1985; Tomasello, Call, Nagell, Olguin, & Carpenter, 1994; Tomasello & Call, 1997) defines two types of ape communicative gestures: ‘intention-movement signals’ and ‘attention getters’. These two categories are distinguished with regards to their acquisition process. Intention-movement signals are acquired through the process of ontogenetic ritualization. In this process two individuals shape each other’s behavior in repeated instances of a social interaction (Tomasello & Call, 1997). For example, in a context of group travel, an infant repeatedly walks up to her mother, turns around into the direction the rest of the group

travels, turns back again, walks up to the mother turns around again and so forth until the mother gets up and starts travelling into the desired direction. Over time the mother anticipates that the infant will perform the same behavior until she starts traveling. Therefore, she gets up after only a few repetitions of the turning around. The infant anticipates the mother's behavior and instead of carrying out the entire behavior, it simply spins around in front of the mother. The key point here is that the behavior leading to the *spin body* gesture was not a communicative signal and only became one by the virtue of mutual anticipations (Halina, Rossano, & Tomasello, 2013). Ontogenetic ritualization predicts that the form of a gesture is derived directly from the interactions between two individuals. Thus, it should lead to substantial variation in individual gesture repertoires because the social interactions differ across dyads and each individual ritualizes different aspects of the same interaction. Even idiosyncratic gestures, i.e. gestures that are only used by one individual, should be possible.

Attention-getters, as the name suggests, serve to attract the attention of another individual to an involuntarily displayed signal, with an especially noisy or salient behavior. In a feeding context, captive chimpanzees often attract the attention of their caregivers by clapping their hands together. Another example could be a juvenile chimpanzee that throws dirt at a potential playmate to draw her attention to his playface. Unlike intention-movement signals, attention-getters are not ontogenetically ritualized but learned in a different way. An individual simply observes that others attend to her upon performing a certain action. Subsequently, this action is produced intentionally with the purpose of drawing attention.

This classical view of ape gesture ontogeny has recently been disputed (Hobaiter & Byrne, 2011). Rather than arising through ritualization, Hobaiter and Byrne argue that all ape gestures are part of a biological inheritance. Based on extensive observations of wild chimpanzee groups in Uganda, they suggest that the lack of idiosyncratic gestures argues against ontogenetic ritualization. Additionally, they found a large overlap between the gestures used by each individual. The size of an individual's repertoire was best predicted by the time the individual was observed, suggesting that, given enough data, every gesture would be observed in every individual at some point. In their view, no major learning process, such as ontogenetic ritualization, is involved in gesture ontogeny. In defense of ontogenetic ritualization Halina et al. (2013) argue that idiosyncratic gestures would be evidence for ontogenetic ritualization but they must not be the norm, since they are constraint

by the form of social interactions, from which the gestures take derive. Similar activities should lead to similar gestures. In their study on captive bonobos, they provide compelling evidence of observational data, tracking the emergence of gestures via ontogenetic ritualization in multiple mother infant dyads. The emergence and ontogeny of ape gestures has never been documented in the wild. Thus the question as to what degree learning is involved in ape gestures is still open.

As mentioned earlier, iconic gestures are typically referential, as they function by inducing the imagination of an absent entity in the receiver. This referential nature makes them different from most ape gestures. Wild apes show almost no signs of referential (triadic) *gestural* communication (Tomasello, 2008; but see Pika & Mitani, 2006); they use their gestures almost exclusively in dyadic contexts. Attention-getters are used to attract attention to the self and not to an outside entity. Intention-movement signals are also used to request a behavior towards oneself. The lack of referential communication amongst conspecifics also holds when we assume that all ape gestures are part of a natural repertoire (Hobaiter & Byrne, 2011). However, there is evidence of apes in captivity producing referential pointing gestures to request food from their human caregivers (Leavens, Hopkins, & Thomas, 2004). Furthermore, Lyn, Russell and Hopkins (2010) showed that the understanding of referential pointing gestures depended on the rearing environment of the subject. Apes that were reared in a complex socio-communicative environment outperformed other apes in their ability to comprehend declarative signals. Recently, a human reared orangutan male has been observed to point for conspecifics (Pelé, Dufour, Thierry, & Call, 2009). To what extent this gesture is understood by his conspecifics is not totally clear, since the conspecifics had independent knowledge about his goal (obtaining a certain kind of token) in the experimental setup (Moore, Call, & Tomasello, In preparation). In general, comprehension of referential gestures seems to be more difficult than production, as it seems to require a substantial amount of experience and interaction with humans (enculturation) (Moore, In press).

None of the theories about the origins of ape gestures suggest that iconicity plays an important role in their gestural communication. In fact, the large-scale observational studies in captivity and in the wild, find no evidence for the use of iconic gestures in chimpanzees or other great apes. Nevertheless, there are some observational studies that find evidence for production and understanding of iconic gestures in great apes.

Tanner and Byrne (1996) reported a number of seemingly iconic gorilla gestures. In a captive group in San Francisco Zoo, a male gorilla indicated iconically to a female playmate the action he wanted her to perform or the direction he wanted her to move. For example, he swung his arm under his body and tapped his genitals. The authors translate this gesture as an invitation to come to the indicated location for sexual contact. Call and Tomasello (2007) suggested that these gestures could also be ritualized intention-movements and the iconicity an interpretation by the human observer. However, Tanner and Byrne reported that the observed gestures did not qualify as intention-movements because they were not incipient actions and did not predict the future actions of the signaler. Rather, the gestures illustrated the desired path of motion the body of the recipient should follow. Furthermore, the male used the iconic gestures towards three different females, all of whom showed similar responses. The authors argued that a comprehension of the iconically depicted motion is more likely to explain these observations than repeated ritualization. More recently, these gestures have been found in other groups of gorillas, suggesting that they might be part of the natural repertoire of gorilla gestures (Genty, Breuer, Hobaiter, & Byrne, 2009). In this case, iconic resemblance might not be the main reason for their production and understanding.

Pika and Mitani (2006, 2009) have argued that high-ranking males used a so-called 'directed-scratch' in mutual grooming sessions to request grooming of certain body parts. One chimpanzee performed a loud and exaggerated scratch on a part of his body while his partner was watching. This led to increased grooming of the scratched spot. The authors claim:

Our observations suggest that the recipient of the signal has an understanding of the intended meaning of the gesture and that wild chimpanzees use gestures to specify an area of the body to be groomed and to depict a desired future action. They therefore qualify as referential and iconic [...]. (p. 192)

This argument suffers from two weaknesses. First, the gesture does not qualify as an iconic gesture, since it is functionally effective and the iconic interpretation only lends itself to a human observer. Second, it is not clear whether or not the scratch is used communicatively at all. One could conceive that the groomed male scratches a body part because he is irritated by parasites in this particular area. Since grooming plays an important role in establishing and maintaining coalitions and alliances, the groomer is well advised to recognize when the partner is bothered by a parasite. High-

ranking males are more likely to be skillful groomers because grooming is essential to the formation and maintenance of effective alliances, which secure the rank of the individual (Moore, In press).

In summary: apes gesture intentionally and flexibly while taking into account the attentional state of the partner. The role that iconicity plays in the comprehension of gestures has not been demonstrated empirically (Call & Tomasello, 2007). To my knowledge, there is no experimental evidence that supports or refutes the understanding of iconicity in great apes. The current study aims to address this question.

The next section outlines the cognitive mechanisms that are necessary to understand an iconic gesture and discusses the evidence concerning these mechanisms in human children and apes.

1.2 COGNITIVE MECHANISMS

In the example given in section 1.1.2 the waiter has to carry out quite a bit of cognitive work to respond to your iconic 'lighter gesture' in the way that you want him to. First of all he has to recognize that you are communicating with him. Then he can go on to identify the aspects of your behavior that are relevant or meaningful and identify them as making a reference to something like a lighter or the act of lighting a lighter. In a final step he has to infer, what your gesture means in the present context, in order to produce the appropriate response.

In the following section I will describe these steps in more detail and discuss them with respect to the socio-cognitive abilities of apes and human children.

1.2.1 Understanding (Cooperative) Communicative Intentions

For your gesture to qualify as a meaningful act of communication, three conditions have to be met: First, you have to intend to produce a particular response in your audience. Secondly, the audience has to recognize your intention to produce this particular response. Finally, you should not try to deceive your audience. This so called Gricean account of meaningful communication was first described by Paul Grice (1957) and has since been modified to the above structure (Moore, submitted; see also Neale, 1992). To return to our example: You have to act with the intention to get the waiter to light your candle. If you were to produce the same hand motion accidentally, it

would not be meaningful at all. Additionally, the waiter has to reason about why you want him to see this particular behavior. That is, he has to grasp that you want him to understand that you want something. Furthermore, you have to intend to evoke this kind of reasoning in him. Finally, you act on the assumption that the waiter will try to figure out what you want from him and that he will be willing to do so. At the same time he acts on the assumption that you are sending an honest signal.

In Tomasello's (2008) view, apes lack the meta-representational abilities to engage in communicative acts that have a Gricean structure, whereas children seem to be competent in this regard from a very early age on (see section 1.1.2). Gomez (1994) admits that apes lack the abilities to engage in truly Gricean acts of communication (involving reasoning about the intentions of others) but he also doubts that children are capable of doing so. In his view the meta-representational abilities of humans enable thinking about the intentional structure of communicative acts, but they are not necessary to act with communicative intention. He argues that it is sufficient for a communicator to produce a sign (e.g. a gesture) that is directed at the receiver while checking her attentional status (which is perceivable by tracking her line of sight) to elicit the desired response and make sure that the sign is seen. The communicator does not have to act with the intention to produce a belief in the receiver, but has to act with the intention to make the receiver perceive something. Furthermore, if both interlocutors are mutually attending to the attentional state of the other, this situation involves an attentional loop that is similar to the intentional loop embedded in truly Gricean communicative acts. Since apes are capable of tracking the attentional states of others (Bräuer, Call, & Tomasello, 2005) and also adjust their communicative behavior accordingly (Call & Tomasello, 2007), it is possible to consider apes to be acting with Gricean communicative intentions.

There are several aspects of your behavior that inform the waiter about your intention to communicate with him. If you would utter your request verbally, he could guess your communicative intent from the fact that you are using words, since words are primarily used for communicative purposes. But, because of the non-verbal nature of your gesture, you provide some additional communicative cues: you perform your action purposely and in combination with ostensive eye contact. These factors play an important role for the understanding of communicative intentions (see for example: Behne, Carpenter, & Tomasello, 2005; Senju & Csibra, 2008). In a recent study, Moore, Liebal and Tomasello (2013) investigated the importance of the various

combinations of these cues for the inference of communicative intent in three-year-old children. In a hiding game they used a light and sound mechanism that highlighted the hiding place of a toy when turned on by a central switch. When the switch was pressed intentionally, the children inferred the communicative intent of the experimenter, even without ostensive gaze. This showed that ostensive cues are not essential for the recognition of communicative intent. They conclude that ostensive cues are helpful to establish a communicative situation but not necessary to maintain it. For your waiter it would be difficult to figure out the meaning of your message if you would produce your gesture without engaging in eye contact. However, if your candle would go out whenever the door of the restaurant opens, after a while, the waiter could understand your gesture without engaging in eye contact.

Moore (submitted) links the basic characteristics of meaningful communicative acts (intending to get a response and recognition of this intention) to two separable actions: intentional production of signs and acts of ostension. In order to produce the intended response in the receiver, the signal has to be adequate and produced with this purpose in mind. The recognition of the signal is ensured by producing it overtly in combination with ostensive cues that serve to engage the attention of the receiver. Adjusting the communicative behavior to the attentional state of the receiver is also regarded as an act of ostension. Since acting this way is sufficient to act with communicative intent, the cognitive complexity necessary to do so is greatly reduced and might be well within the scope of apes and infants abilities. Even though explicitly understanding communicative intent is cognitively more demanding than acting with it, recognizing acts of ostension might be implicit and therefore cognitively unchallenging. All that is left is the explicit interpretation of the signal. Since ape gestures are either ritualized or shaped by natural selection, they are understood straightforwardly. Through reinterpretation of the behaviors that are necessary for Gricean communication, Moore (following Gomez) therefore argues that it is theoretically plausible to assume that apes act with and also understand communicative intent.

But even if the cognitive structure of communicative acts turns out to be less complex than originally thought, their understanding relies on the assumption of mutual cooperativeness. As mentioned above, you are acting on the assumption that the waiter will be willing to interpret your message and comply with your request whereas the waiter acts on the assumption that you are not trying to deceive him.

Based on a wealth of empirical data, Tomasello and colleagues argue that apes do not understand cooperative communicative intentions. In several studies, based on an object-choice paradigm, in which apes were given cues to help them choose between two containers to locate a reward, they found that chimpanzees do not understand cooperative cues (e.g. pointing) but do use competitive cues (e.g. a 'stop' gesture accompanied by an utterance in a negative verbal tone) to locate a reward (Herrmann & Tomasello, 2006). In general, they seem to be better at competitive than at cooperative cognitive tasks (Hare & Tomasello, 2004). Tomasello (2008) argues that apes communicate with gestures almost solely to request things imperatively. Their comprehension abilities reflect this in that they are able to understand imperative but not cooperative communicative acts. Understanding cooperatively provided iconic gestures should be beyond the communicative ability of apes. However, Moore (In press) argues that even though apes are less cooperative than humans, this is not the reason for their failure to understand cooperative cues in object-choice tasks. He refers to recent studies in which a competitive setup of an object-choice task did not improve their performance when using the same kind of cues (pointing gestures) that were used as cooperative cues in the earlier studies (Tempelmann, Kaminski & Liebal, forthcoming). Moore suggests that chimpanzees seem to be willing to cooperate but do not understand what the experimenter wants. In his view, they are poor at identifying the precise referent of the gesture. Since iconic gestures are typically referential, apes should not be able to understand them on his account either. However, in the case of cooperatively provided iconic gestures, it is impossible to tell whether the cooperative or referential nature (or the combination) poses the main problem for apes.

In contrast to apes, human children have been shown to possess the necessary socio-cognitive abilities from an early age and should therefore not be troubled by this component of understanding iconic gestures (Tomasello, 2008).

So, while children are very apt at understanding cooperative communicative intentions, however complex they are, it is still an open question to what extent the same is true for apes.

1.2.2 Recognizing Iconicity

The recognition of communicative intentions is tightly interwoven with the communicative signal that is used. So, in the case of our example at the restaurant, the next step for our waiter would be to make the connection between your gesture and lighting a lighter. Whereas deictic and conventional gestures are completely underdetermined when viewed out of (shared) context, an iconic gesture partly constricts its potential referents by re-presenting the referent behaviorally. For example: by simulating an action that is not currently happening (such as lighting a lighter). Iconic gestures contain some information about their referent and could be called *evidence-rich*, i.e. they present additional information about the communicator's message, in comparison to deictic and conventional gestures (Moore, in press). Nevertheless, recognizing the referent of a gesture based on its iconicity is cognitively demanding.

Donald (1991) claims that understanding and production of iconic gestures is enabled by mimetic skill. He defines mimetic skill as a multimodal modeling system that allows any voluntary action to be stopped, replayed and edited under conscious control. In combination with an episodic memory system, isolated aspects of episodes can be re-enacted and used as a means of communication by translating event perceptions into actions, using the whole body. Even though the mimetic mechanism is basically a motor adaptation, it is supramodal at the output, so that hands, feet, posture, locomotion, voice or any combination of these can be used to construct a representation. According to Donald, mimesis first emerged with *Homo erectus* and therefore apes do not possess mimetic skill. On this account, understanding and production of iconic gestures is outside the communicative ability of apes.

Tomasello (2008) links production and understanding of iconic gestures to skills involving imitation, simulation or symbolizing and doubts that apes possess these kinds of skills. In this context, imitation is the ability to reproduce, potentially after a single observation, not only the intended goal of another's action but also the means by which it is achieved (Tomasello & Carpenter, 2005; Arbib, Liebal, & Pika, 2008). Imitation may be the key skill involved in recognizing iconicity. A precondition for the imitation of an action is the ability to isolate the characteristic aspects of it from the rest of the surrounding behavior. For example: If you want to imitate someone lighting a lighter with her right hand, you have to pay attention to the way the lighter is held and the way the thumb is moved. The actions of the left hand and the bodily posture or the facial expression of your

model are irrelevant. Furthermore, to truly imitate the behavior, you have to process the way the lighter was lit in order to reproduce the same behavior. The same skill is required to recognize an iconic gesture, since the behavioral sequence that comprises the gesture needs to be isolated from the observed actions. In the case of the iconic “lighting” gesture, you have to remember the way the lighter was lit in order to recognize resemblance between the gesture and the original action. This is a precondition for the recognition of the *mechanically ineffective* (intransitive) gesture as corresponding to the *functional* action.

Human children show extensive imitative skills from a very early age (see e.g. Meltzoff & Williamson, 2010). Imitation also plays a very important role in language acquisition and has been proposed to be the main mechanism by which children acquire their vocabulary (Moore, 2012; Tomasello, 1999, 2008). Human children also use their imitative skills more reliably in novel problem solving tasks than great apes do. In general, apes tend to emulate (copying effects instead of actions), rather than imitate others actions in experimental problem solving contexts (Tennie, Greve, Gretscher, & Call, 2010). Chimpanzees also fail to imitate novel actions that are not already part of their behavioral repertoire (Tennie, Call, & Tomasello, 2012). In terms of communicative signals, imitation seems to play no role in the acquisition of new gestures in great apes (Call & Tomasello, 2007; Hobaiter and Byrne, 2011). It has been argued that apes possess a less developed type of imitative skills called “simple imitation” (Arbib et al, 2008). This allows them to copy actions by observation after a prolonged time of exposure, depending on the complexity of the task (Byrne, 2003; Arbib et al, 2008). This is supported by observational studies on wild apes that report cases of action copying (e.g. Byrne, 2003; Hobaiter & Byrne, 2010). There is also some evidence that apes recognize, when humans imitate them (Haun & Call, 2008). Considering this evidence, it seems justifiable to ascribe apes a rudimentary skill for imitation, which allows them to recognize the correspondence between an observed action and their own action, at least after a prolonged period of exposure.

To sum up: Children show imitative abilities that are suppositional for understanding iconic gestures. Apes seem to possess a rudimentary form of imitative abilities that enable them to copy actions that are within their behavioral repertoire. Therefore, apes might show some ability to understand iconic gestures, most likely after a prolonged period of exposure to either the gesture, or the action from which it is derived.

1.2.3 Completing the Message: Common Ground

So far, the waiter has figured out that you are trying to communicate with him and that your message has something to do with a lighter or the lighting of one. Even though the iconic gesture you use contains some information regarding the referent, it is still underdetermined, at least in the present context. It would allow multiple interpretations, such as “Have you seen my lighter?” or “I like lighting lighters”. It requires more inference to determine the precise referent of your gesture and your social intention (i.e. what you want from the recipient) regarding this referent. In order to infer your communicative goal, the waiter has to rely on your shared common ground - that is your mutual knowledge, mutual beliefs and mutual assumptions (e.g. Clark & Brennan, 1991; Clark 1996). The communicative context, in which your message is understood, exceeds the immediate environment and includes everything that both of you assume as relevant (and assume that the other one assumes that this is relevant) for your social interaction. This includes your shared past, the way that people usually behave in certain situations, cultural habits and also facts about the world (Tomasello, 2008). In the example, you go on and point to the candle to help the waiter decipher your message. This limits the possible interpretations of your iconic gesture but he still has to know that people like lit candles on their tables while eating dinner in a restaurant and that people usually attract the attention of a waiter when they want something. In fact, the choice of your communicative signal was already based on the assumption of a common ground, since you probably never witnessed this particular waiter handling a lighter. However, you have witnessed other waiters to do so and therefor assume that waiters in general know how to handle a lighter.

Human infants are already very good at producing and interpreting communicative gestures based on common ground. At 18 month they point more often to a picture that shows a toy from an earlier play session, but only if they are interacting with their former playmate (Liebal, Carpenter, & Tomasello, 2010). At the same age they resume an activity, which they have been engaged in previously, when their former partner points to an object that has been part of their shared activity (Liebal, Behne, Carpenter, & Tomasello, 2009). With increasing age, children also begin to form an understanding of cultural common ground. Three-year-olds assume that an adult, who is confronted with two objects of different cultural prevalence, is communicating about a culturally novel object, when ambiguously requesting information (Liebal, Carpenter, & Tomasello, 2013).

To my knowledge, there are no systematic studies that have investigated the role of shared experience and common ground in ape communication. In other domains, such as collaboration, they do keep track of past experiences with other individuals and act according to them in the future (Melis, Hare, & Tomasello, 2006, 2008). However, this behavior seems to be based on the cognitively rather simple mechanisms of “emotional bookkeeping” as opposed to the formation of explicit knowledge about the interactions with the partner (Schino & Aureli, 2009). The latter would be necessary for the establishment of common ground.

Moore (in press) argues that the inability to track common ground explains apes’ failure in many object choice tasks. Enculturated apes perform better in these tasks because, over a long period of time, they have acquired extensive information about humans’ means and reasons to communicate. On his account, great ape communication is different from human communication as it relies more on naturally meaningful signals or the use of gestures that are related to naturally meaningful action schemas. These signals are *evidence-rich* as they offer the recipient a lot of information about the communicative goal of the communicator. Common ground seems unnecessary in such a communicative setting. Furthermore, he argues, it is cognitively very demanding to track the knowledge states of others and the extent to which these overlap with our own. Compared to pointing gestures or verbal utterances, iconic gestures are *evidence-rich*. However, as I have argued earlier, their understanding still requires common ground and therefore should be difficult for apes to do so right away.

1.3 CURRENT STUDY

Experimental studies show that human children understand and produce iconic gestures in communicative settings from around 26 month of age. However, it is unclear whether children treat iconic gestures differently from arbitrary gestures. It might be that human children have a general understanding of when someone is acting with communicative intent. The question then would be, whether or not they perceive an arbitrary gesture as a means of communication.

In contrast, there have been no experiments investigating whether or not apes understand iconic gestures, either immediately or after prolonged exposures. Similarly, there is no experimental evidence, whether or not apes treat iconic gestures differently from arbitrary gestures.

The aim of the current study was to address these questions by comparing chimpanzees and four-year-old human children in their ability to use iconic and arbitrary gestures in a decision making task. The current study was based on the logic of an object-choice task (e.g. Herrmann, Melis, & Tomasello, 2006). A gesture was presented as a cue for the subject to decide between two locations, of which only one yielded a reward. The relationship between the gesture and the location was either iconic or arbitrary. Since iconic gestures are principally used to communicate about actions, the experimenter indicated the reward-yielding location by referring to an action, rather than an object, that was associated with it. The actions used were derived from a mutual activity between the subject and the experimenter to ensure visual and motoric experience with the actions. The experimenter established a cooperative relationship with the subject. He produced the gestures intentionally and in combination with ostensive eye contact (see figure A1.1 in the appendix). However, they were never highlighted by other communicative means (e.g. verbally or pointing) as being communicative. The communicative nature of the gestures had to be inferred by the subject.

The study was designed as a within-subject experiment, so that each individual served as its own control. Each subject experienced two conditions in a counterbalanced order: one using arbitrary gestures and the other using iconic gestures. This allowed for possible transfer and order effects to be investigated. It was expected that children, but not apes, treat iconic gestures differently from arbitrary gestures from the very beginning. Therefore they were expected to choose the indicated side more often when referred to by an iconic gesture than when referred to by an arbitrary gesture.

To take into account the problems that apes have with understanding referential gestures, cooperative communicative intentions and establishing and updating of common ground, chimpanzees, but not children, received a large number of test trials. In this way, it should be possible to disentangle these problems from their ability to differentiate iconic and arbitrary gestures. The numerous repetitions of the same procedure should give them the opportunity to perceive the variable aspects of the procedure (i.e. the gesture) independent of the communicative components of the situation. It was expected that chimpanzees treat iconic gestures differently as arbitrary gestures over time. That is, they were expected to reach a certain level of performance faster when using iconic gestures as when using arbitrary gestures.

2 METHODS

This study aimed to investigate the use of iconic gestures in a decision making task in chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*).

Data collection for the chimpanzees took place between June 2012 and January 2013. The chimpanzees were tested at the Wolfgang Koehler Primate Research Center (WKPRC), located at the Zoo Leipzig in Leipzig, Germany.

Data collection for the children took place in February 2013. The children were tested in various kindergartens throughout the Leipzig area.

The study was approved by an internal ethical committee of the Max Planck Institute for Evolutionary Anthropology.

In the following section subjects, testing facilities and equipment are described separately for chimpanzees and children.

2.1 CHIMPANZEES

2.1.1 Subjects

In total, 15 chimpanzees participated in the study. All chimpanzees were born in captivity and housed at the WKPRC at the Zoo Leipzig. Table 2.1 provides details of all chimpanzees that participated in the study at any time. The animals are treated according to the global strategies of the European Endangered Species Program (EEP). They live in two separated stable groups, group A and B. In June 2012 group A consisted of 17 chimpanzees. In the course of data collection one individual left the group, resulting in a final group size of 16. Group B consists of 6 individuals. Both groups spend most of their time in a semi-natural habitat including a large outdoor and indoor enclosure. These enclosures are equipped with climbing structures, artificial streams and ponds to withdraw water, artificial termite mounds and poking boxes. Furthermore, there are separate sleeping, retreat and observation rooms for each species. In total, Group A has a living environment of 4533 m² and Group B of 1740m².

The chimpanzees are fed three times a day with a diet consisting of a variety of fruits, vegetables, cereals and cooked meat. Every day there is an additional enrichment feeding. None of the subjects were food or water deprived at any time. Their participation in the study was voluntary and all rewards for participation were [additional](#) to their usual diet.

All of the subjects belong to the subspecies Western Chimpanzee (*Pan troglodytes verus*), except for Sandra and Alex, who are hybrids of Western and Eastern Chimpanzee (*Pan troglodytes schweinfurthii*). All of the tested chimpanzees had prior experience with studies on social and physical cognition. 4 of the 15 chimpanzees (Annett, Alexandra, Natascha and Pia) had to be excluded from the study, either due to a lack of motivation to participate (Annett, Alexandra and Natascha) or due to transfer to another Zoo (Pia). The remaining subjects included 6 females and 5 males with an age range from 7 to 36 [years](#) (Mean: 18.36[yrs](#)).

TABLE 2.1. Information about sex, age at beginning of the study, group membership, sequence of experimental conditions (see table 2.2.) and data status for all chimpanzees that participated in the experiment

Subject	Sex	Age (years)	Chimpanzee Group	Order	Data Status
FRAUKJE	f	36	A	Arb - Icon	com
FRODO	m	18	A	Icon - Arb	com
KARA	f	7	A	Icon - Arb	com
KOFI	m	7	A	Icon - Arb	com
LOME	m	11	A	Arb - Icon	com
NATASCHA	f	32	A	Arb - Icon	arb
PIA	f	13	A	Icon - Arb	icon
ROBERT	m	36	A	Icon - Arb	com
SANDRA	f	19	A	Icon - Arb	com
ALEX	m	11	B	Arb - Icon	com
ALEXANDRA	f	12	B	Icon - Arb	icon
ANNETT	f	12	B	Icon - Arb	-
FIFI	f	19	B	Arb - Icon	com
GERTRUIDA	f	19	B	Arb - Icon	com
JAHAGA	f	19	B	Icon - Arb	com

Arb – Icon = arbitrary condition before ICONIC condition; Icon – Arb = ICONIC condition before arbitrary condition. Com = complete data for both conditions; icon = ICONIC condition; arb = arbitrary condition; f = female; m= male

2.1.2 Test Facilities

Each chimpanzee was tested individually in an observation room located adjacent to the indoor enclosure of the respective group. Chimpanzees entered the observation room either from the indoor enclosure or via a tunnel system from their sleeping room. Testing took place between

8:30am and 12:30am. A line drawing of the observation rooms of group A and B are given in in figure 2.1 and 2.2.

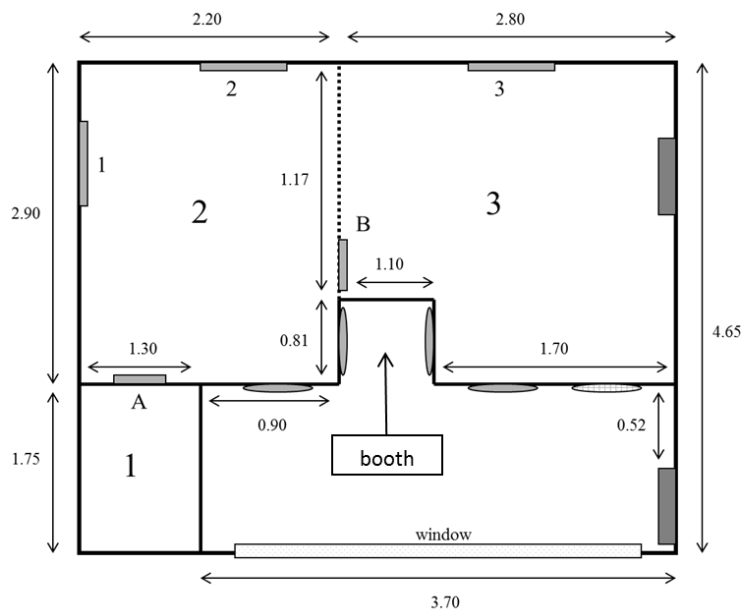


FIGURE 2.1. Group A observation room, view from above, distance in meters. Large Arabic numerals indicate the room number.

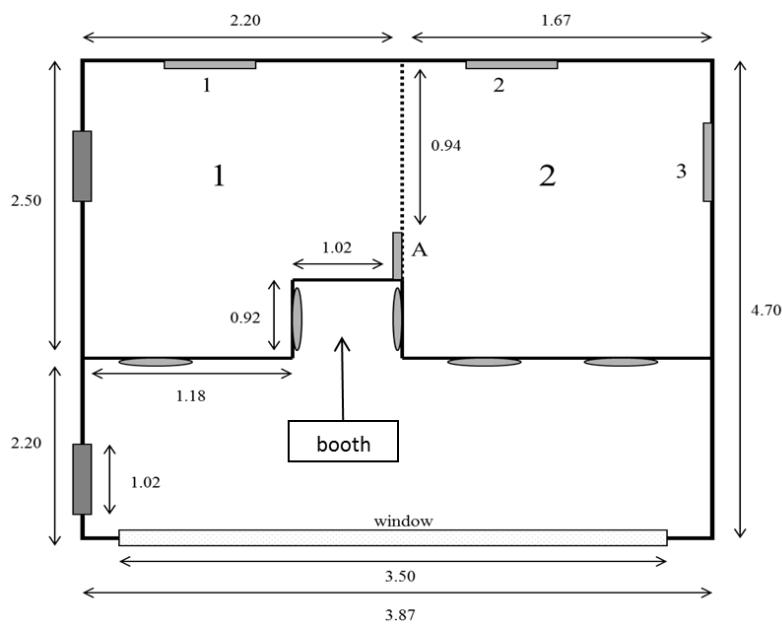


FIGURE 2.2. Group B observation room, view from above, distance in meters. Large Arabic numerals indicate the room number.

For group A the relevant rooms 2 and 3 combined cover an area of 13.61m^2 , for group B rooms 1 and 2 cover an area of 8.74m^2 . The experimenter was located in the small block-out (hereafter: booth) between room 2 and 3 for group A or between room 1 and 2 for group B, respectively, initially facing away from the large window in his back. In both rooms, the longer side of the booth comprised a small mesh at the bottom (height: 42cm), a large window (height: 234 cm) and another small mesh at the top (height: 40 cm). The shorter sides flanking the booth in both rooms were identical and comprised a small mesh at the bottom (height: 42cm), a section in which mesh and Plexiglas panels could be flexibly interchanged within a metal frame (height: 58cm), a large window (height: 176cm) and another mesh at the top (height: 40cm). For the current study clear Plexiglas panels were inserted to the sections on the left and right side. In the *ICONIC* condition the used apparatus were attached to these panels. In the *ARBITRARY* condition the panels had small holes at the bottom through which food could be delivered to the subject. For the current study the hydraulic door separating the two large rooms ('B' in the sketch for Group A; 'A' in the sketch for Group B) was left open, so that the subject could roam freely between the two rooms.

2.1.3 Apparatus and Experimental Setup

To investigate the use of iconic and arbitrary gestures in a decision making task, subjects were tested in two different experimental conditions. Following the logic of an object choice task (see for example Hermann, et al., 2007) subjects had to decide between one of two potential alternatives based on an experimenter given cue.

The basic setup was the same in both conditions (see figure 2.3 for a schematic drawing of the setup). The experimenter sat on a small stool, placed inside the booth, facing towards the window in the opposing wall. A single camera attached to a large tripod was located just outside the booth, behind the experimenter providing a full shot of the experimental setup.

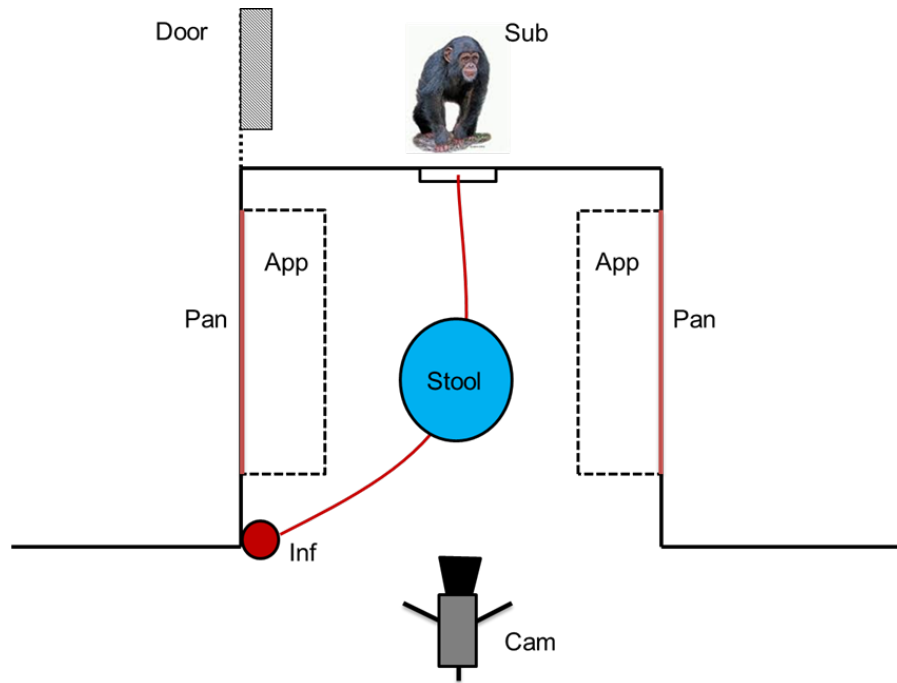


FIGURE 2.3. Schematic drawing of the experimental setup and the camera position for the chimpanzees. App = apparatus attached to the panel (only in *ICONIC* condition); Cam = camera on large tripod; Inf = infusion bottle with hose; Pan = Plexiglas panel; Sub = starting position of subject.

In order to center the subject in front of the experimenter at the beginning of every trial, an infusion bottle filled with diluted grape juice was attached to a screw on the left side of the left panel. A small hose went from the infusion bottle, underneath the stool, to the lower mesh in the booth's front wall. There it ended in a Plexiglas tube, which was attached to the mesh (see figure 2.4). By operating a small wheel, the experimenter could start and stop the juice flow. A bucket with the rewards (Dustless Precision Pellets, 300mg, Banana) was placed behind the experimenter, underneath the tripod.

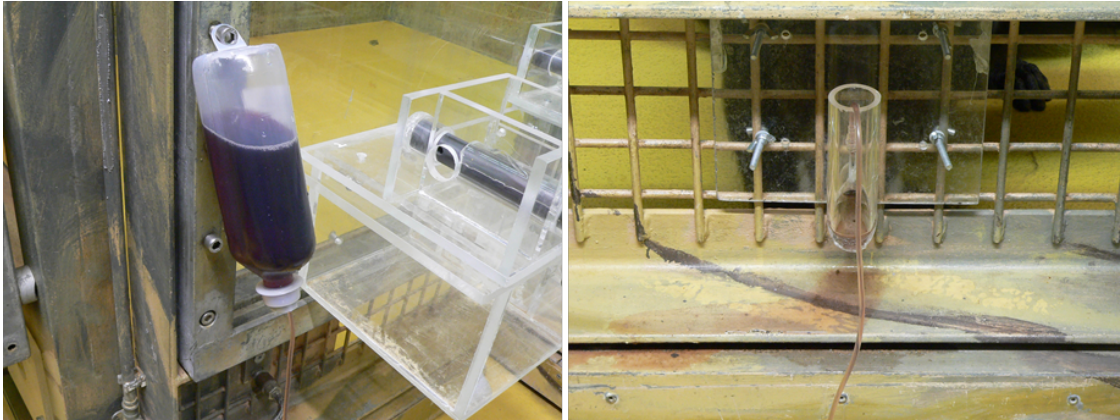


FIGURE 2.4. Photos of the juice dispensing equipment (infusion bottle on the left, Plexiglas tube on the right).

In the ICONIC condition two apparatus were attached to the left and the right panel (see left picture in figure 2.6) flanking the booth. The apparatus consisted of two main parts, a ‘basic box’ and an interchangeable functional attachment.

The ‘basic box’ was the same for both apparatus. It was a cuboid box made from Plexiglas (50cm x 25cm x 17.5cm) that was divided up into three compartments (width: 18cm/10cm/18cm) rectangular to its longer side. A notch (8.5cm x 2.5cm) was drilled into the lower middle of the longer side that matched a corresponding notch in the Plexiglas panel, granting the subject partial access (fingers without thumb) to the front part of the middle compartment. Inside the middle compartment a separate roof-shaped Plexiglas element (hereafter: releaser) was located between two barriers. Screwed to its top was a metal hook. The general mode of operation for every functional attachment was to tighten a small rope that went through the metal hook, thereby lifting the releaser and releasing a banana pellet over the barrier within the subject’s reach.

The functional attachments were all made out of Plexiglas and could be bolted to a surface on top of the ‘basic box’. There were four sets of functional attachments labeled A, B, C and D (Figure 2.5). Each set comprised two identical, mirror inverted elements that enabled releasing the reward to the subject by carrying out a distinct action. The same action had to be performed by the subject and the experimenter simultaneously. Therefore, one end of the functional attachment reached inside the subject’s cage, either through a hole in the Plexiglas panel or through the mesh above the apparatus. Operating the apparatus alone did not yield a reward. By operating the apparatus together with the experimenter, the subject gained visual and motor information about the

corresponding actions. Functionally ineffective versions of the actions, carried out to operate each set, were later on used as gestures.

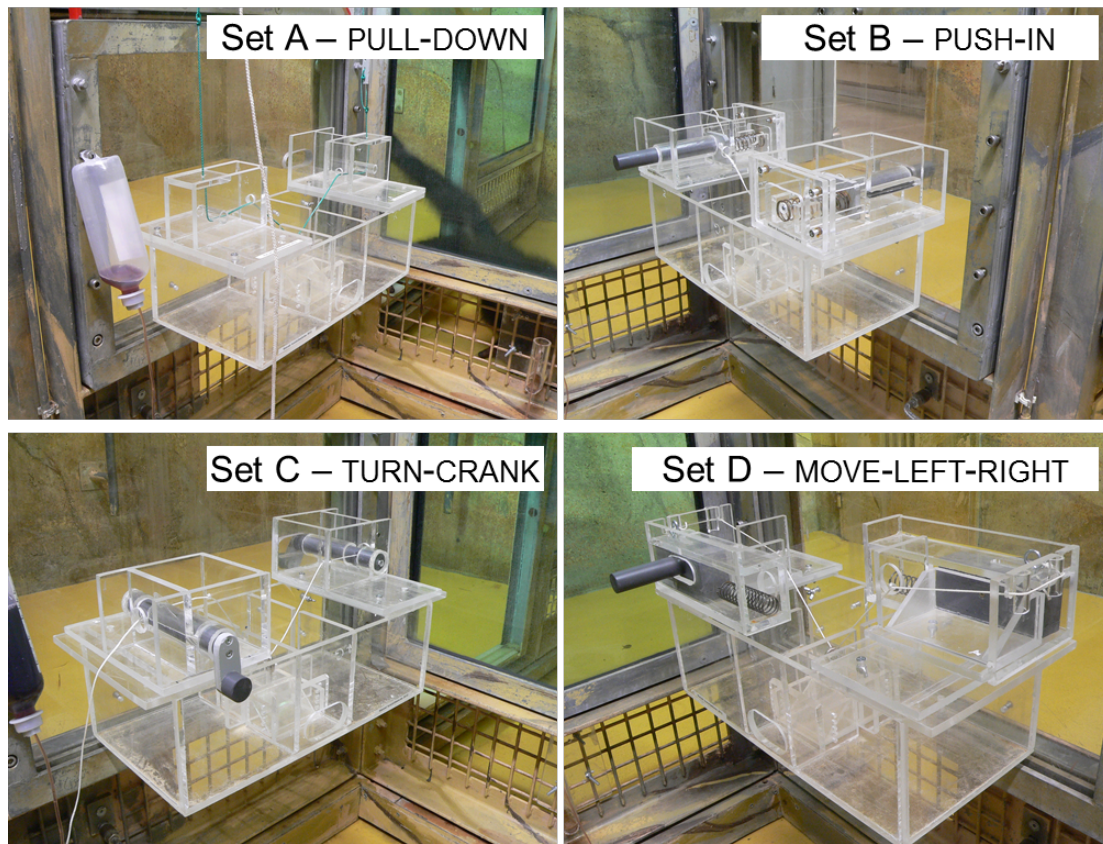


FIGURE 2.5. Photos of the four sets of functional attachments as used in the ICONIC condition (attachments bolted to the basic box)

Set A - PULL-DOWN. The reward was released when the subject and the experimenter both pulled on a rope that went through the metal hook on top of the releaser. One end of the rope reached through the upper mesh inside the subject's cage. The other end went through a plastic component attached to the experimenter's side of the mesh. To prevent the rope from being pulled through, a stopper was fixed to the rope. To operate the apparatus, the experimenter grabbed the rope with his left hand in front of his face and pulled it down vertically. The subjects' actions varied within and between subjects.

Set B - PUSH-IN. The reward was released when the subject and the experimenter both pushed in a lever, thereby tightening a rope attached to the levers that went through the metal hook on top of the releaser. Upon letting go, the lever was pushed back into its initial position by a spring located

behind it. To operate the apparatus, the experimenter put his left palm to the front of the lever [at chest level](#) and pushed it in horizontally. The subjects' actions varied within and between subjects.

Set C - TURN-CRANK. The reward was released when the subject and the experimenter both turned a crank, thereby tightening a rope that was attached to the subject's crank, passed through the metal hook on top of the releaser and went on through the experimenters crank. To operate the apparatus, the experimenter closed his left hand around the crank's handle [at chest level](#) and turned it counter-clockwise. The subjects' actions varied within and between subjects.

Set D – MOVE-LEFT-RIGHT. The reward was released when the subject and the experimenter both moved a lever from left to right, thereby tightening a rope attached to the levers that went through the metal hook on top of the releaser. Upon letting go, the lever was pushed back into its initial position by a spring located next to it. To operate the apparatus, the experimenter closed his left hand around the lever [at chest level](#) and pushed it horizontally to the right. The subjects' actions varied within and between subjects.

In the ARBITRARY condition no apparatus were attached to the Plexiglas panels flanking the booth. The inserted panels had holes in the bottom through which a reward could be given to the subject.

The gestures that were used throughout the experiment were functionally ineffective versions of the actions described for set A, B, C and D, resulting in 4 distinct gestures: A*, B*, C* and D*. These gestures were always paired in the following way: A* + B* and C* + D*. The same gestures were used in the ICONIC and in the ARBITRARY condition

The apparatus and the experimental setup were identical for chimpanzee groups A and B

2.1.4 Experimental Design

Each individual was tested in two experimental conditions, the ICONIC and the ARBITRARY condition, enabling a within subject comparison of the results for both conditions. The order in which the conditions were administered was counterbalanced across subjects. Therefore subjects were randomly assigned to one of two groups (see table 2.1 and table 2.2). Before each condition subjects received training (see section 2.1.5).

Each gesture was randomly assigned to one of the sides of the booth. This was counterbalanced across subjects and conditions but remained constant within condition for each individual.

In the **ICONIC** condition the apparatus corresponding to the assigned gesture was attached to the respective panel. Hence, the main difference between the two conditions was the relationship between the gesture and the corresponding side. In the **ICONIC** condition the gesture matched the action needed to operate the apparatus. In the **ARBITRARY** condition there was no such relationship between gesture and side. Each group started with the gestures **A*+B*** in the first condition and continued with **C*+D*** in the second (see table 2.2).

TABLE 2.2 Sequence of conditions and gestures

		A* + B*		C* + D*	
Group 1	TRAINING	ICONIC	TRAINING	ARBITRARY	
Group 2		ARBITRARY		ICONIC	

Subjects were tested for 12 trials (= one session) on each test day. Before the beginning of the experiment subjects received training trials to familiarize them with the setup and the apparatus. At the beginning of each trial the experimenter sat on the small stool, placed inside the booth, facing towards the window in the opposing wall. The subject was centered at the opposite side of the window by dispensing juice from the infusion bottle. Each trial began with dispensing juice to the subject and ended with the subject receiving a reward.

2.1.5 Training Procedure

The setup for the training conditions was identically to the corresponding experimental conditions.

In the training for the **ARBITRARY** condition the experimenter stopped the juice flow, turned to one of the two sides and offered a reward through the notch in the panel. If the subject did not automatically come to the respective panel, the experimenter called the subject’s name and knocked the reward against the panel to attract the subject’s attention. Upon arrival the subject received the reward and the experimenter turned back to his initial position. Then the next trial began. Subjects received this kind of training until they reliably followed the experimenter’s turn. The training trials in the **ARBITRARY** condition were conducted directly before the first experimental session.

In the training for the ICONIC condition both apparatus were baited with a banana pellet. After each trial the experimenter re-baited the operated apparatus.

The experimenter stopped the juice flow, turned to one of the two sides and operated the apparatus on his own without emitting a reward. If the subject did not automatically come to the respective panel, the experimenter called the subject's name and continued to operate the apparatus on his own. Upon arrival the subject and the experimenter operated the apparatus together, whereupon the subject received the reward. Since the subject was unfamiliar with the apparatus in the beginning, the experimenter encouraged her to learn to operate it. Therefore he tapped the panel close to functional attachment reaching into the subject's cage. Subjects received this kind of training until they reached the learning criterion (see section 2.1.6). The sequence of sides to which the experimenter turned was pseudo- randomized with the same number of turns for both sides and never more than two turns in a row to the same side.

Subjects were non-differentially reinforced, that is, they received a reward (handed over from the experimenter or upon operating the apparatus) even when the initial decision was coded as wrong (see section 2.1.7).

2.1.6 Test Procedure

The test trials followed the same general procedure as described for the training trials. The decisive differences are described below.

Instead of turning to one of the sides, the experimenter called the subjects name and started gesturing as soon as the subject visually attended to him. The gesture always indicated the side to which the experimenter turned afterwards (see 2.1.4).

Gestures were executed in three blocks of four gestures each (i.e. 12 gestures per trial). Before each block, the experimenter made sure that the subject visually attended to him. If this was not the case, he called the subjects name again until he regained her attention.

As soon as the subject decided for one of the sides by moving away from her initial position towards one of the panels, the experimenter turned to the side that he indicated with the gesture.

If the subject started moving before the experimenter fully executed the first gesture, the trial was repeated.

If the subject did not move until the end of the three blocks, the experimenter turned to the indicated side.

One subject (Fifi) refused to move away from her initial position until the experimenter had turned to one of the sides. Therefore the procedure was changed slightly. The experimenter waited until the subject made a decision. However this had no effect on coding (see next section).

The sequence of gestures was pseudo-randomized with the same number for each kind of gesture and never more than two of the same kind of gesture in a row.

Each subject was tested for a maximum of 25 sessions (= 300 trials) in each condition. If a subject performed above chance (at least 10 out of 12 trials correct; binomial test, $p < 0.05$) in two consecutive sessions she moved on to the next condition.

2.1.7 Data Coding and Reliability

All trials were filmed with a single digital video camera. The camera captured the entire experimental setup (Figure 2.6 shows snapshots for both conditions).

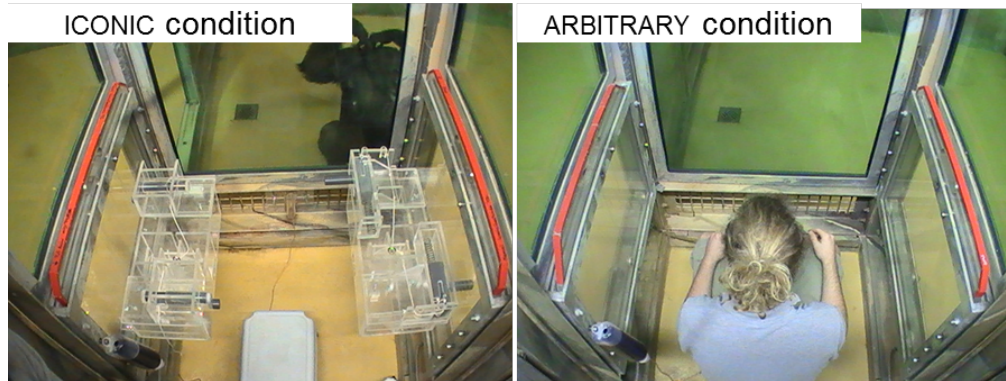


FIGURE 2.6. Snapshots from original videos. Left: ICONIC condition; right: ARBITRARY condition

The main point of interest was the subject's behavior following the gestures in the experimental conditions. The subject's response was coded as 'left', 'right' or 'no response'. 'Left' was coded if the subject moved from its initial position towards the left panel, as seen on the video. 'Right' was coded if the subject moved from its initial position towards the right panel, as seen on the video. 'No response' was coded when the subject did not move towards either of the panels within the time frame of the onset of the first gesture and three seconds after the last gesture. In ambiguous cases (e.g. subject moved to the left and turns around before reaching the panel) the response was

coded as 'left'/'right' when a part of the subject's body was visible through the left/right panel, as seen on the video.

The subject's response was then compared with the side indicated by the experimenter. All matches were numerically coded as (1) and mismatches were coded as (0). The code 'no response' automatically led to a mismatch and was coded as (0). Therefore a maximum score of 12 was possible for each session. Sessions in which the subject yielded scores of 10 or higher were considered as above chance (binomial test, $p < 0.05$).

The experimenter coded all trials live and again from video. A second coder, unfamiliar with the purpose of the study, coded 15 % of all experimental trials (1272 in total) randomly selected. There was a very high agreement of 96.5% between the initial and the naïve coder ($\kappa = .965$).

2.2 CHILDREN

In the child study we replicated as closely as possible the methods of the chimpanzee study. The following sections describe the adjustments that needed to be made.

2.2.1 Subjects

In total, 29 four-year-old children from 6 different kindergartens participated in the study. Table 2.3 provides an overview of all children that participated in the study at any time. They were recruited from a database of children in kindergartens, whose parents volunteered for studies on child development. Some of the children had participated in other studies on cognitive development. They were seen in their regular kindergarten for two sessions, which lasted approximately 20 minutes each and were spread over a maximum of five days. All children were native German speakers and came from a mixed socioeconomic background. Five children had to be excluded from the study because they did not complete both conditions (four children) or because of experimental error (one child). Complete data was collected for 24 children (12 girls, 12 boys, mean age = 4.58 years: range = 4.07 years to 4.95 years).

TABLE 2.3. Information about sex, age at beginning of the study, group membership, sequence of experimental conditions (see table 2.2.) and data status for all children that participated in the experiment

Subject	Sex	Age (years)	Kindergarten	Order	Data Status
BoTi	m	4.19	AnSc1	Arb - Icon	com
CHCo	m	4.56	AlBu31	Icon - Arb	com
CoNi	f	4.90	RoHa2	Arb - Icon	com
DeEL	f	3.99	Reich5	Arb - Icon	arb
GLLU	f	4.68	RoHa2	Arb - Icon	com
GoMi	f	4.59	Goet24	Icon - Arb	com
GrLU	f	4.16	AnSc3	Icon - Arb	com
GrSo	f	4.71	AlBu30	Arb - Icon	com
HaMi	f	4.20	Goet22	Arb - Icon	com
HoBr	m	4.07	Born185	Icon - Arb	com
HoHa	m	4.73	AlBu32	Icon - Arb	com
JeAN	m	4.95	Born186	Icon - Arb	com
KrPA	f	4.72	AnSc4	Icon - Arb	icon
MoSA	f	4.86	RoHa2	Arb - Icon	com
NaMi	f	4.84	RoHa2	Icon - Arb	com
PeMA	m	4.23	Reich5	Arb - Icon	com
ReJU	m	4.42	Reich5	Arb - Icon	arb
RiLE	m	4.54	Born187	Icon - Arb	com
RuDA	m	4.91	AlBu33	Icon - Arb	-
RuTi	m	4.41	Goet23	Arb - Icon	com
ScHA	m	4.33	Reich5	Icon - Arb	com
SCLi	f	4.23	AnSc2	Arb - Icon	arb
ScSu	f	4.80	AnSc5	Icon - Arb	com
SHAf	f	4.77	Born184	Arb - Icon	com
StPA	m	4.95	RoHa2	Icon - Arb	com
ThAM	m	4.84	Reich5	Arb - Icon	com
ToEM	f	4.75	Goet21	Arb - Icon	com
WeLi	f	4.34	Born188	Icon - Arb	com
ZiLo	m	4.48	Reich5	Arb - Icon	com
BoTi	m	4.19	AnSc1	Arb - Icon	com

Arb – Icon = ARBITRARY condition before iconic condition; Icon – Arb = iconic condition before ARBITRARY condition. Com = complete data for both conditions; icon = iconic condition; arb = ARBITRARY condition; f = female; m = male

2.2.2 Test Facilities

The children were tested one-by-one in a familiar room inside their kindergarten. All necessary equipment was transported to the kindergarten. The experimenter introduced himself to the children while they were still in their daily group. He asked the respective child, if she wanted to play a marble game with him in a different room. Together they went to the test room.

2.2.3 Apparatus and Experimental Setup

The setup was modeled on the setup for the chimpanzees. A schematic drawing can be seen in figure 2.7.

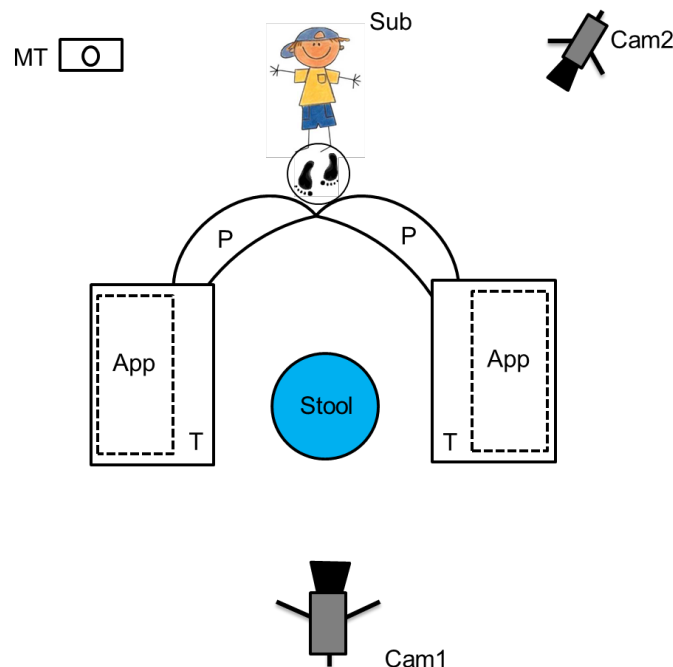


FIGURE 2.7. Schematic drawing of the experimental setup and the camera position for the child study. App = apparatus bolted to a wooden table (only in iconic condition); Cam1 = camera on large tripod; Cam2 = second camera.; MT = “Marble Tower”; P = half-moon shaped pillow, T = wooden table; Sub = starting position of subject

The experimenter sat on a small stool, placed between two wooden tables (50cm x 59cm x 50cm; 42cm x 54cm x 50cm). One camera was attached to a large tripod and located behind the experimenter, yielding a full shot of the experimental setup. Another camera was placed behind the subject, opposite the experimenter. To separate the subject from the experimenter, two half-moon shaped pillows (27cm x 33cm x 95cm) were placed in front of the experimenter. The subject’s starting position was marked by a piece of cardboard with footprints on it. A clear Plexiglas tube (height: 59cm, holding capacity: 39 marbles) vertically glued to a Plexiglas plate was located behind the subject’s starting position. Rewards were marbles that the child could collect by dropping them into the Plexiglas tube and thereby creating a “Marble Tower”. No additional reward was given to the children. Earlier studies (Fletcher, Warneken, & Tomasello, 2012) and piloting showed that collecting the marbles was motivation enough for the children.

The same apparatus that were used for the chimpanzee study were also used for the child study. The apparatus were disinfected and all elements that had been in contact with the chimpanzees were replaced.

In the **ICONIC** condition the apparatus were bolted to the wooden tables flanking the experimenters stool.

In the **ARBITRARY** condition two identical bowls, into which the experimenter dropped the marbles, were placed on the tables.

The only functional attachment that had to be modified was set A - **PULL-DOWN** (see figure 2.8). A wooden lath (height: 39cm) was bolted to both elements of set A. The rope that lifted the releaser went through holes on top of the lath. To make it easier for the child to pull down the rope, both ends were formed as a loop. Piloting ensured that the children were able to operate all apparatus.

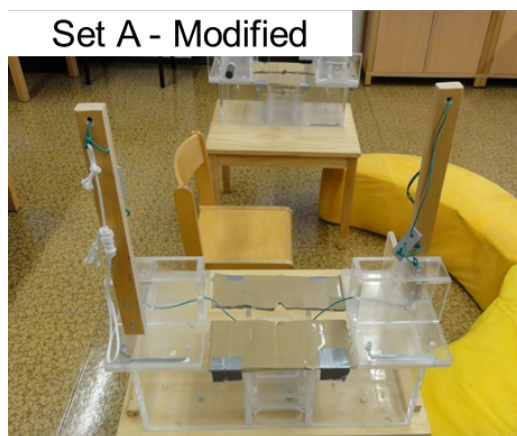


FIGURE 2.8. Modified functional attachment for set A

The top of the basic box was covered with cardboard (see figure 2.8) in order to prevent the subject from reaching directly for the marble. The gestures used were the same as described for the chimpanzees.

2.2.4 Experimental Design

The experimental design was the same for both species (see section 2.1.4).

Children completed more trials on each test day. For them, each experimental session comprised 24 trials. However, each child received only one session per experimental condition.

2.2.5 Training Procedure

Training for each condition took place directly before the experimental sessions. A protocol for the German verbal instructions can be found in the appendix.

Upon entering the experimental room the subject was introduced to the Plexiglas tube and the logic of collecting the marbles in order to build the “Marble Tower”. Three marbles were placed around the tube and the subject was encouraged to put them in the tube. Then the experimenter said: “I know a game we can play to get more marbles for the tower, do you want to try it?” He then led the subject to her starting position and sat down on the small stool facing towards the child.

On the second day the child was asked if she remembered the marble game from the day before. The experimenter allowed the subject to again put three marbles into the tube, whereupon he led her to the starting position.

To start the training, the experimenter called the subject’s attention and said: “Look what happens now!”

In the training for the *ARBITRARY* condition, the experimenter turned to one of the two sides and dropped a marble into the bowl on the table. If the subject did not automatically come to the respective table, the experimenter called the subject and made an encouraging movement with his head. Upon arrival the subject received the marble and was allowed to put into the “Marble Tower”. The experimenter turned back to his initial position and as soon as the child returned to her starting position, the next trial began. Subjects received 12 trials of this kind.

In the training for the *ICONIC* condition, both apparatus were baited with a marble. After each trial the experimenter re-baited the operated apparatus.

The experimenter turned to one of the two sides and operated the apparatus on his own without emitting a reward. If the subject did not automatically come to the respective apparatus, the experimenter called the subject, made an encouraging movement with his head and continued to operate the apparatus on his own. Upon arrival the subject and the experimenter operated the apparatus together, whereupon the subject received the marble. Since the subject was unfamiliar with the apparatus in the beginning, the experimenter encouraged her to learn to operate it.

Therefore, he tapped the functional attachments and encouraged the child verbally, without naming the action. Subjects received 12 trials of this kind.

The sequence of sides, to which the experimenter turned, was pseudo-randomized with the same number of turns for both sides and never more than two turns in a row to the same side.

Subjects were non-differentially reinforced, that is, they received a marble even when their initial decision was coded as wrong (see section 2.2.7).

2.2.6 Test Procedure

The test trials followed the same general procedure as described for the training trials. The decisive differences are described below. A protocol for the German verbal instructions can be found in the appendix.

After the last training trial, the experimenter stood up, led the subject to the “Marble Tower” and said: “Wow, we have already collected a lot of marbles, but we need more to finish the tower. Do you want to continue? Do you want to play the game a little bit differently?” If the subject agreed, he led her back to her starting position and placed himself on the stool, facing towards the child.

Instead of turning to one of the sides, the experimenter called the subject’s attention. As soon as the subject visually attended to him he said: “Let’s get the marble” and started gesturing. The gesture always indicated the side to which the experimenter turned afterwards (see 2.1.4).

Gestures were executed in three blocks of four gestures each (i.e. 12 gestures per trial). Before each block the experimenter made sure that the subject visually attended to him. If this was not the case, he called the subject’s name again until he regained her attention.

As soon as the subject decided for one of the sides by moving away from her initial position towards one of the tables, the experimenter turned to the side that he indicated with the gesture. Instead of walking towards one table many subjects decided by pointing to one of the tables. In those cases the experimenter always encouraged the child to walk to the indicated table no matter if the choice was correct.

If the subject started moving or pointed before the experimenter fully executed the first gesture, the trial was repeated.

If the subject did not move towards one of the tables by the end of the three blocks of gestures, the experimenter turned to the indicated side for the first three trials of each session. During piloting some children went to the “Marble Tower” upon the verbal instruction or asked the experimenter which marble they should get. Therefore, in the fourth trial, the experimenter pointed to both sides simultaneously and encouraged the child verbally to go to one of the sides without saying which side was correct.

The sequence of gestures was pseudo-randomized with the same number for each kind of gesture and never more than two of the same kind of gesture in a row.

Each subject was tested for one session in each condition. Taken together with the training trials each child completed 36 trials on one day. Children generally enjoyed the procedure.

2.2.7 Data Coding and Reliability

All trials were filmed with two cameras on videotape. One camera captured the entire experimental setup (Figure 2.9 shows snapshots for both conditions). The second camera filmed the experimenter.



FIGURE 2.9. Snapshots from original videos. Left: ICONIC condition; right: ARBITRARY condition

The main point of interest was the subject’s behavior following the gestures in the experimental conditions. The subject’s response was coded as ‘left’, ‘right’ or ‘no response’. ‘Left’ was coded if the subject moved from its initial position towards the left table, as seen on the video. ‘Right’ was coded if the subject moved from its initial position towards the right table, as seen on the video. “No response” was coded when the subject did not move towards either of the tables within the

time frame of the onset of the first gesture and three seconds after the last gesture. The subject's response was then compared with the side indicated by the experimenter. All matches were numerically coded as (1) and mismatches were coded as (0). The code 'no response' automatically led to a mismatch and was coded as (0). Therefore a maximum score of 24 was possible for each session.

The experimenter coded all trials live and again from video. A second coder, unfamiliar with the purpose of the study, coded 25% of all experimental trials (312 in total) randomly selected. There was a very high agreement of 97% between the initial and the naïve coder ($\kappa=0.972$).

2.3 DATA ANALYSIS

The data was analyzed in two consecutive steps. In a first step, a combined model, comparing the performance of children and chimpanzees was calculated. In a second step, the chimpanzee data was taken to a further analysis to investigate their performance over time.

2.3.1 *Combined Analysis*

To take into account the difference in number of trials per sessions and number of sessions in general, only the first 24 trials per condition and subject (= 48 trials per subject) were incorporated into the model. For the children, this was equal to their overall number of trials, for the chimpanzees, the first two sessions per condition were combined to reach an equal number of trials per subject and condition.

To test the explanatory power of the predictor variables, we ran a generalized linear mixed model (GLMM) with binomial error structure and logit link function. In the model, the predictor variables were tested against the response variable, which was defined as the proportion of correct trials. The predictor variables of interest were the species of the subject (Human or Chimpanzee), the sex of the subject (Female or Male), the age of the subject, the order in which these conditions were administered (ICONIC – ARBITRARY OR ARBITRARY – ICONIC) as between subject effect and the condition of the response (ICONIC OR ARBITRARY) as within subject effect. These variables were included as fixed effects into the model. To investigate whether the two species and/or order-groups perform differently in the two conditions, interactions up to the third order were included for condition,

species and order. Furthermore, we included the interaction of age and species to detect potential age effects within species. Due to the within-subject design of the experiment, subject identity was included as a random effect, together with the subject's peer group (kindergarten for the children, chimpanzee group for the chimpanzees). Furthermore, a random slope was assigned for the difference between the conditions within each subject. In order to investigate the effects and their interactions in more detail, the analysis was repeated for each species separately using the same model. The final sample included 35 subjects (24 children and 11 chimpanzees) in 9 groups resulting in $N=70$.

To assess the explanatory power of the predictor variables, the full model was compared against a model with the same random effects but without species and condition as predictor variables using a likelihood-ratio test. Collinearity between the predictor variables was low (maximum variance inflation factor (VIF) = 2.52) and the stability of the estimates for each predictor variable was acceptable.

All models were computed in *R* 2.15.2 (R Core Team, 2012) using the function *lmer* of the package *lme4* (Bates, Maechler, & Bolker, 2012) and all graphs were created using Microsoft® Excel®.

In a follow up analysis we tested, whether the performance of the two species in the two conditions differed from a performance expected by chance. The assumption of normal distribution of the data within each combination of species and condition was met; therefore one-sample t-tests were conducted. These analyses were computed in IBM® SPSS® Statistics version 20.0.0.

2.3.2 Chimpanzees' Performance over Time

To investigate the question whether or not chimpanzees differentiate between iconic and arbitrary gestures over time, the number of sessions needed to reach a certain level of performance was assessed per subject and condition. Two different criteria were applied:

Criterion 1 (C1): Performance above chance in two consecutive sessions (i.e. min. of 10 out of 12 trials correct per session; binomial test, $p<0.05$)

This criterion corresponds to the initial learning criterion. If a subject reached this criterion, she moved on to the next condition or finished the experiment. As noted earlier, subjects were non-differentially reinforced. Making mistakes was therefore not very costly. Hence, a second, slightly

relaxed, criterion was applied to account for the potentially reduced motivation to make a correct choice.

Criterion 2 (C2): Performance above chance in two combined sessions (i.e. min. of 18 out of 24 trials correct; binomial test, $p < 0.05$)

As mentioned in section 2.1.6 each chimpanzee was tested for a maximum number of 25 sessions. If a subject did not reach the learning criterion after 25 sessions, the minimum number sessions possible to reach the criterion, if testing would have continued (i.e. 27), was assigned to the performance in this condition. The final sample for this analysis included 11 subjects (N=22).

The differences in performance between the two conditions were not normally distributed. Therefore a non-parametric Wilcoxon signed ranks test was used to compare the performance in the *ICONIC* and the *ARBITRARY* condition within subjects. Due to the small amount of variation in the data regarding the *ARBITRARY* condition, it was not possible to analyze the effects of age, sex and order on the performance over time in a single model. Pairwise comparisons using Mann Whitney U-tests and Spearman's rank correlation were computed instead. Considering the small sample size, exact instead of asymptotic tests were used (Mundry & Fischer, 1998). All tests were two tailed and with an alpha-level of 0.05. These analyses were computed in IBM® SPSS® Statistics version 20.0.0.

3 RESULTS

The first analysis shows the results of the combined analysis for children and chimpanzees in the first 24 trials per condition. The second analysis presents the results for chimpanzees' performance over time.

3.1 COMBINED DATA ANALYSIS

Table 3.1 presents the mean proportion of correct trials depending on the various predictor variables.

TABLE 3.1. Mean proportion of correct trials for within and between subject predictor variables.

Species	<i>Within Subject</i>		<i>Between Subject</i>			
	Condition		Order		Sex	
	ICONIC	ARBITRARY	Arb - Icon	Icon - Arb	Female	Male
HUMAN	0.68	0.53	0.54	0.67	0.64	0.57
CHIMPANZEE	0.42	0.40	0.35	0.47	0.38	0.45

The mean proportion of correct trials is calculated by summing up the number of correct trials per individual per condition with respect to the predictor variable and then dividing it by the number of subjects and the number of received trials (i.e. 24). Order: Arb – Icon = ARBITRARY condition before ICONIC condition; Icon – Arb = ICONIC condition before ARBITRARY condition.

On a descriptive level, children had a higher proportion of correct trials in the ARBITRARY (0.53) and the ICONIC (0.68) condition than the chimpanzees (ARBITRARY: 0.40; ICONIC: 0.42). On an individual level, no chimpanzee performed above chance (i.e. min. of 18 out of 24 trials correct; binomial test, $p < 0.05$) in either the ARBITRARY or the ICONIC condition. Five (out of 24) children performed above chance only in the ICONIC condition and three (out of 24) children performed above chance in both conditions. No child performed above chance only in the ARBITRARY condition. Six of the eight children that performed above chance in the ICONIC condition received this condition first. All three children that performed above chance in the ARBITRARY condition received this condition after the ICONIC condition.

The comparison of the full model against a model that lacked species and condition as predictor variables showed that these variables had explanatory power ($\chi^2 = 20.59$, $df = 6$, $p < 0.01$). In a stepwise procedure, the non-significant 3-way interaction between condition, species and order

was removed ($\beta = -0.36 \pm 0.65$, $z = -0.55$, $p = 0.56$) then the non-significant 2-way interactions between species and order ($\beta = 0.33 \pm 0.47$, $z = 0.71$, $p = 0.48$), species and age ($\beta = 0.74 \pm 0.71$, $z = 1.0$, $p = 0.30$) as well as between condition and order ($\beta = 0.14 \pm 0.31$, $z = 0.46$, $p = 0.65$) were removed. The final model included species, condition, order, sex, age and the interaction between species and condition as fixed effects. A summary for these effects and their estimates is presented in table 3.2.

TABLE 3.2. Effects of predictor variables on the performance in the experiment; Response variable: proportion of correct trials.

Predictor Variables	Estimate (β)	SE	z	p
INTERCEPT	-0.367	0.459	-0.799	0.424
SPECIES	0.339	0.374	0.906	0.365
CONDITION	0.095	0.265	0.358	0.720
ORDER	0.656	0.220	2.987	0.003**
SEX	-0.176	0.220	-0.800	0.424
AGE	-0.018	0.020	-0.891	0.373
SPECIES*CONDITION	0.768	0.325	2.366	0.018*

Species indicates the species membership of the subject (Human or Chimpanzee), Condition indicates the condition of the session (ICONIC or ARBITRARY), Order indicates the order of the experimental conditions (ICONIC-ARBITRARY or ARBITRARY – ICONIC), Sex indicates the sex of the subject (Female or Male), Age indicates the age of the subject. * $p < 0.05$; ** $p < 0.01$.

First we investigated the main effects of the model. We found a significant main effect of order ($p < 0.01$). Children and chimpanzees who received the ICONIC condition before the ARBITRARY condition performed significantly better compared to those who received the ARBITRARY condition first.

Furthermore, we found a significant interaction between species and condition ($p < 0.05$). Children, performed better in the ICONIC condition compared to their own performance in the ARBITRARY condition and the overall performance of the chimpanzees. The singular analysis showed that children's performance was also above chance in this condition (one sample t-test, $t = 4.309$, $df = 23$, $p < 0.001$). All other performances were not significantly different from chance level (ARBITRARY children: $t = 0.738$, $df = 23$, $p = 0.47$; ICONIC chimpanzees: $t = -2.061$, $df = 10$, $p = 0.07$; ARBITRARY chimpanzees: $t = -2.204$, $df = 10$, $p = 0.052$). The performance of the chimpanzees could be considered a trend ($p < 0.1$), in the direction that chimpanzees performed below chance in both conditions. Figure 4.1 presents the mean proportion of correct trials across species and conditions.

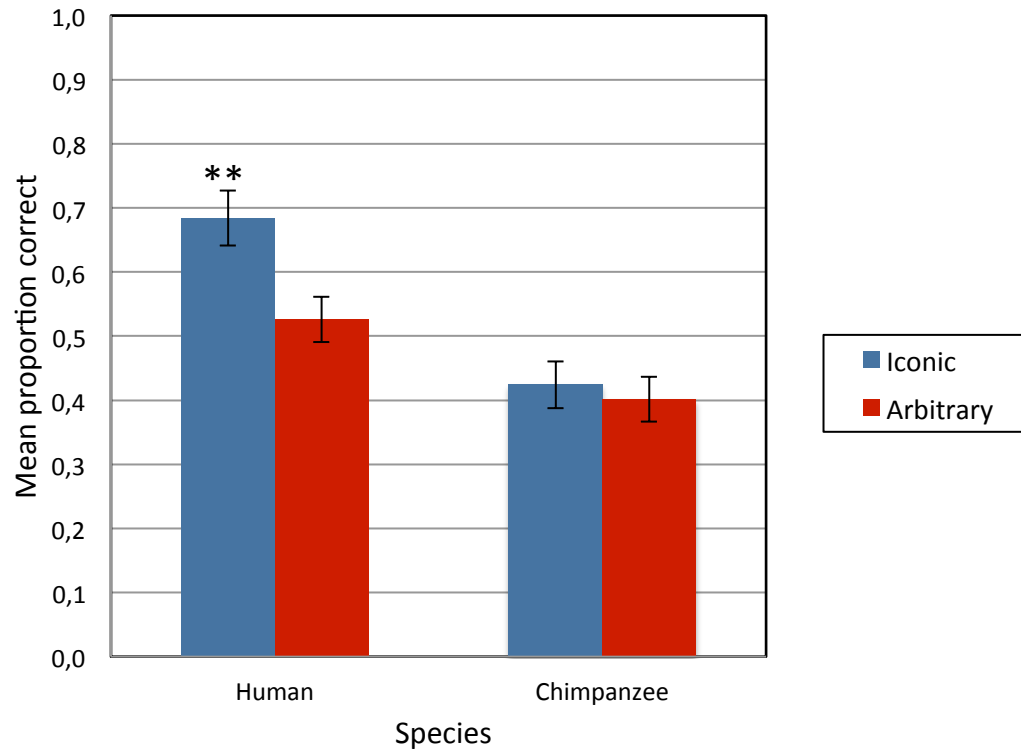


FIGURE 3.1 Mean proportion of correct trials (+SE) across the two species for each condition, ** $p < 0.01$.

3.2 CHIMPANZEES' PERFORMANCE OVER TIME

Two chimpanzees (Kofi and Sandra) reached C1 in the ICONIC condition and one chimpanzee (Alex) reached C1 in the ARBITRARY condition within the 25 testing sessions. Six subjects (Alex, Gertruida, Lome, Frodo, Kofi and Sandra) reached C2 in the ICONIC condition and one individual (Alex) did so in the ARBITRARY condition within testing time. Three of the subjects who reached C2 in the ICONIC condition received this condition first and three received the ARBITRARY condition first. Alex was the only subject who managed both conditions with respect to C2. Table 3.3 presents the performance of all chimpanzees for both criteria.

TABLE 3.3. Number of sessions needed to reach the two performance criteria.

Name	Criterion 1		Criterion 2	
	ICONIC	ARBITRARY	ICONIC	ARBITRARY
ALEX	27*	20	13	19
FIFI	27*	27*	27*	27*
FRAUKJE	27*	27*	27*	27*
GERTRUIDA	27*	27*	25	27*
LOME	27*	27*	17	27*
FRODO	27*	27*	10	27*
JAHAGA	27*	27*	27*	27*
KARA	27*	27*	27*	27*
KOFI	16	27*	16	27*
ROBERT	27*	27*	27*	27*
SANDRA	19	27*	18	27*

Criterion 1 = min. of 10/12 trials correct in two consecutive sessions; *Criterion 2* = min. of 18/24 trials correct in two combined sessions. 27* indicates that the criterion was not reached (27 = minimum number of sessions needed to reach the criterion, if testing would have continued).

There was no significant difference between the two conditions with respect to C1 ($Z = -1.07$, $p = 0.5$). For C2, we found a significant difference between the two conditions ($Z = -2.20$, $p = 0.031$). Chimpanzees needed significantly fewer sessions to reach C2 in the ICONIC than in the ARBITRARY condition. There was no significant effect of order ($U = 15$, $p = 1$), age ($\rho = 0.56$, $p = 0.07$) or sex ($U = 4$, $p = 0.052$) on subjects' performance in the ICONIC condition. Age and sex could be considered as a trend ($p < 0.1$) in the direction that younger individuals tended to perform better in the ICONIC condition than older ones and males tended to perform better than females. As mentioned earlier, it was not possible to investigate possible interactions between these variables. Given the small sample size of these between subject comparisons, it might well be that they rely heavily on the performance of single individuals. Note that those individuals, who reached C2, but not C1, did so not in the very last sessions. This suggests variation of the performance over time.

4 DISCUSSION

4.1 OVERVIEW

This study investigated the ability of four-year-old human children and chimpanzees to understand iconic and arbitrary gestures. The main questions were whether children and chimpanzees use these gestures differently to guide their decision and whether the two species differ with respect to their usage. To investigate these questions I tested 24 children and 11 chimpanzees in a decision making task. Iconic and arbitrary gestures served as cues to indicate a reward yielding location. The iconicity was determined by the presence of an apparatus in this location. A functionally ineffective version of the action, that was needed to operate the apparatus, was used as the gesture to indicate this location, thereby establishing an iconic relationship between gesture and location. The same gestures were then used as arbitrary gestures, though there was no such relationship as there were no apparatus present. For each subject I collected data on her decisions with regard to the indicated location for both gesture types. Each individual was tested in both conditions for 24 trials. Chimpanzees received further more trials to investigate if they learned over time to use the gestures differently. Therefore a criterion of successful learning was specified.

The results showed that children, but not chimpanzees, can understand iconic, but not arbitrary gestures as cues to make a correct decision right from the start. Chimpanzees do not show understanding of either kind of gesture within the first 24 trials. Irrespective of species, subjects performed better in both conditions when they started with the ICONIC condition. Age and sex had no significant influence on the performance. Over time, chimpanzees reached the learning criterion in fewer sessions in the ICONIC condition compared to the ARBITRARY condition

Children seemed to be able to recognize iconic gestures as a means of communication and understand the message that is conveyed. The order effect suggests that iconic gestures served to establish a communicative interaction in which, to some extent, also arbitrary gestures were perceived as communicative. Chimpanzees did not understand iconic gestures immediately, but they could learn to use the information faster than with arbitrary gestures. Iconic gestures seemed to provide 'non-conventional' information that is available to both species.

4.2 DISCUSSION OF MAIN RESULTS FOR CHIMPANZEES

Chimpanzees showed no immediate understanding of either kind of gesture in the current study. This failure cannot be explained by a lack of motivation, as they always corrected their choice to retrieve a reward. In fact, all chimpanzees that were not food motivated were excluded from the study (see section 2.1.1).

Other reasons for their failure could be [inadequacy](#) of the communicative signal, a lack of understanding of the situation as communicative and/or cooperative or the inability to establish common ground. [All of which could be interrelated.](#) Merely the intentional and ostensive production of a signal [may](#) not be enough to denote communicative intent, if the signal itself is not meaningful [to](#) the recipient (Moore, et al., 2013). Great ape communication [is characterized by](#) unintentionally produced expressive states (sometimes accompanied by intentionally produced attention-getters) [and](#) intentionally produced (phylo- or ontogenetically) ritualized signals. There is little to no evidence that chimpanzees produce [or](#) understand iconic gestures (Tomasello, 2008; Hobaiter & Byrne, 2011), suggesting that iconic gestures are not immediately meaningful for them and therefore unsuitable to establish a communicative interaction. It might even be that apes do not differentiate between the intention to communicate and the signal that is used. [They might only recognize the communicative intention of a signaler if the signaler is using a familiar signal.](#) In this view, intentional and ostensive production alone is not sufficient to indicate the communicative nature of [a](#) behavior. Only 'naturally meaningful' signals can be highlighted as [being communicative and for](#) a certain recipient in this way. Following the above line of argument, keeping track of common ground is not necessary in great ape gestural communication because the signal is unambiguous and not understood [within a shared context](#). If the signal is not understood [immediately](#), the absence of common ground might prevent the recipient from reasoning about the sender's reasons to communicate. To decipher the sender's message, the receiver would [need](#) to infer potential meanings of the message based on explicit knowledge of earlier interactions with the sender. Without this knowledge, the signal is not considered to be potentially meaningful. Unfortunately, it is not possible to disentangle these components on the basis of the current study.

The chimpanzees tested for this study [did](#) show some abilities to use iconic gestures as a source of information after a prolonged time of exposure. The large number of trials might have

compensated for their deficit to understand cooperative communicative intentions and/or common ground. Even if they never grasped the communicative nature of the interaction, the repetitions helped to differentiate the static and variable parts of the situation. With everything else staying the same, the gesture emerged as the only variable, [which could differentially influence the subject's decision](#). The results therefore showed that some chimpanzees have a rudimentary ability to recognize the similarity between a gesture and an action. The inability to use arbitrary gestures in the same way showed that this was not due a general ability to use any kind of gesturally provided information or general associative learning ability. The iconic gesture served to make a reference to the respective apparatus.

Most likely, this reference was not understood in an insightful manner. That is, the iconic connection between the gesture and the action was not recognized in a singular instance. The performance of the apes that reached C2 but not C1 indicated a lot of variation in their performance. The four subjects that reached C2 but not C1 did not reach C2 in their last sessions but earlier. Therefore, a high [proportion](#) of correct choices did not always result in a further increase, which would be expected for an insightful understanding of the referential connection. [An insightful understanding of the referential connection should at some point have resulted in a sudden increase of performance, followed by the maintenance of this high level.](#) If [the chimpanzees](#) would have grasped the communicative nature of the situation, they might have paid more attention to the gesture. Attention to the experimenter and/or the gesture might have also been increased if the subjects would have been differentially reinforced. In the current study, they were rewarded even when their initial decision was wrong, in order to prevent a decrease of motivation. Both factors might have increased the overall speed of learning. So, in the current study, the iconic gesture simply increased the tendency to choose the indicated side, speaking against an insightful understanding of the referential connection.

Over time, the action at the apparatus might have been absorbed into their behavioral repertoire and the gesture served to elicit a representation of the action. In this way the subjects were inclined to choose the indicated side. This view is line with the imitative abilities of chimpanzees (Arbib, et al., 2008, Byrne, 2003; Tennie, Call, & Tomasello, 2012). They are sometimes able to copy an action that is part of their behavioral repertoire, but fail to copy novel actions. This study showed that the

recognition of familiar actions might also be possible for functionally ineffective (intransitive) versions of these actions (i.e. iconic gestures).

4.3 DISCUSSION OF MAIN RESULTS FOR CHILDREN

Some children showed an immediate understanding for the iconic gestures as a cooperative communicative cue to the reward yielding location. That is, some of the children were able to recognize the iconic gesture as reference to the action that was performed mutually in one of the two locations. This finding is in line with earlier studies that showed an understanding of iconic gestures in even younger children (Namy, 2008; Namy, et al., 2004). In the study by Namy (2008), the iconicity of the gesture was introduced in an earlier introduction phase by showing the child what is usually done with a certain object and encouraging the child to interact with the object in this specific way. In the current study, the action on the apparatus, which was later on used as an iconic gesture, was not actively introduced to the child. The experimenter always operated the apparatus in the same way, but children were not taught to use it in a specific way and found their own way of operating it. This provided a more naturalistic approach to the understanding of iconic gestures. Furthermore, the introduction phase and the training trials did not establish a communicative interaction with regard to the choice the children had to make in the experimental trials. The switch to a communicative interaction was rather sudden. Based on ostensive and intentional production of the gesture, children had to infer that the experimenter's gesture was communicative. The results showed that they made this inference only when the gesture was iconic.

Children did not perform better than chimpanzees regardless of condition. Their performance in the ARBITRARY condition was not different from chance and therefore similar to the performance of the chimpanzees. One could argue that children might have understood the arbitrary gestures as communicative but simply failed to understand the message that was conveyed. However, due to the standardized setup and the multiple repetitions, the potential referents were very restricted. Furthermore, as noted in section 2.2.6, the experimenter pointed to the two potential referents simultaneously, if the child did not make a decision in the first three trials. Therefore, their performance should have improved over time, which was not the case. The failure to use the

arbitrary gesture as a cue showed that ostensive and intentional production of the gesture, in combination with directed speech, was not sufficient for children to infer that the gesture was communicative and informative [in the present study](#).

The failure [in the arbitrary condition](#) cannot be explained by a general inability to understand the arbitrary gesture as communicative, as three children performed above chance in the ARBITRARY condition. However, they only did so after having received the ICONIC condition first. In general, the effect of order showed that children performed significantly better when they received the ICONIC condition first. The arbitrary gesture did not suffice to establish a communicative interaction. It was only seen as communicative after a communicative interaction had already been established in the ICONIC condition. These findings suggest that a suitable means of communication facilitates the start of a communicative interaction (see also Moore, et al., 2013). Once established, arbitrary communicative signals can be introduced and are more easily perceived as communicative. This interpretation is supported by the importance of pointing gestures in early language acquisition (e.g. Bruner, 1983, Tomasello, 1988; Tomasello, et al., 2007). Pointing, as a 'natural' form of communication, helps to establish a communicative interaction that paves the way for the acquisition of arbitrary linguistic symbols.

4.4 EVOLUTIONARY IMPLICATIONS

Following the gestural theories of language evolution, iconic gestures seem to be a suitable starting point for the cultural evolution of a communicative repertoire. They denote their referent not via a mutually shared, arbitrary convention but via re-presenting the referent. Therefore, they can be produced and understood with only a limited amount of earlier interaction between the interlocutors. The results of the current study support this theory.

Once the necessary socio-cognitive infrastructure had evolved, iconic gestures could be used as a 'natural' form of communication. The current study showed that human children, who possess the necessary infrastructure (Tomasello, 2008; see also section 1.2), understand iconic gestures that are derived from a mutual activity. [Iconic gestures](#) were suitable to establish a communicative interaction when produced intentionally and in combination with ostensive cues [while arbitrary gestures, produced in the same way,](#) were [not](#). Early humans could have used iconic gestures as a

starting point to communicate about perceptually absent entities. Once communicative interactions (or communicative routines) were established, the way was paved for more arbitrary means of communication. One way this could have happened is via a “drift to the arbitrary”, as observed in the emergence of sign languages (Tomasello, 2008). On this account, iconic gestures became more and more arbitrary as outsiders imitated the gestures for their communicative end without the original common ground. That is, they observed the result of a communicative interaction between two interlocutors and imitated the same gestures used in the observed communicative interaction to achieve the same outcome. Over time, the gestures became detached from their original meaning and their usage became conventional. If both interlocutors were aware of their communicative interaction, completely arbitrary gestures could have also been introduced and absorbed into their shared common ground.

[Apes](#) showed some ability to use the information contained in iconic gestures after a prolonged time of exposure in this study. This ability could be the [evolutionary basis](#) for the recognition and production of iconic gestures in [humans](#). With the necessary socio-cognitive and socio-motivational infrastructure emerging, actions already in the behavioral repertoire could have been used communicatively. Unfamiliar actions could have been added once the imitative abilities had sufficiently increased (see also Arbib, et al., 2008).

4.5 LIMITATIONS

There are two [potential](#) limitations of the study. In the **ICONIC** condition the food reward/marble was visible or at least known to be present to the subject. For the children this might have made it easier to identify the referent because the verbal instruction asked them to “get the marble”. In the **ARBITRARY** condition no marble was present in the bowls. This might have made it harder for the children to [conceive](#) of a potential referent of the gesture. However, as noted in section 2.2.6, the experimenter simultaneously pointed to both reward locations after three trials without a decision.

[The](#) potential referents of the gesture should be clear by then, [at the latest](#).

For the chimpanzees the presence of the food reward might have had a negative effect on their performance in the **ICONIC** condition. Chimpanzees are known to be very focused on and easily distracted by food. Therefore, the presence of the food reward might have drawn their attention

away from the gesture. However, the experimenter only performed the gestures while the subject was visually attending to him, thereby ensuring that the subject saw it.

Another possible limitation is the absence of an apparatus in the ARBITRARY condition. On the one hand, the absence might have made the ARBITRARY condition less interesting for the subject. This might have resulted in a general loss of motivation. On the other hand, the argument could also be turned around. The presence of an apparatus might have distracted the subjects and drawn their attention away from the gesture. Future studies should avoid this possible confound and present an apparatus in the ARBITRARY condition, which involves an action that is unrelated to the gesture.

4.6 OUTLOOK

There are several ways in which the results of the present study could be followed up by future studies to investigate the nature of potential carriers of content and their role in establishing and sustaining communicative interaction. In the following section I will briefly outline some possibilities.

(1) Instead of linking the apparatus to an action and producing iconic gestures to refer to them, the apparatus could be linked with a distinctive sound. This sound could be used to refer to the apparatus, creating an onomatopoetic relationship between apparatus and sound. In the arbitrary version of this setup, the sound would have an arbitrary relationship with the indicated side. An advantage of this setup would be that no visual attention has to be paid to the experimenter. The results would show whether or not children and chimpanzees understand onomatopoetic relationships. The results could be compared with the present study to see if there are differences between visual and audible cues that resemble their referent.

(2) Following the study of Moore, et al (2013), the production of the gestures could be varied in terms of intentionality (unintentional vs. intentional) and ostension (with vs. without direct eye contact and/or directed speech), to determine the necessary preconditions for the understanding of communicative intentions for children and chimpanzees. For chimpanzees, this would require an extensive training period to ensure the understanding of the gesture when produced intentionally and with ostensive cues.

(3) In section 4.3 I suggested that a 'natural' form of communication (pointing or iconic gesture) is necessary to establish a communicative interaction and introduce more arbitrary signals. One way to test this in children would be to combine an arbitrary gesture with a pointing gesture for a few trials and then only use the arbitrary gesture to indicate the correct side.

(4) In a competitive setup chimpanzees' abilities to extract information out of conspecifics behavior could be investigated. The question would be whether they know what others have done solely based on the observation of their bodily movements (and not their manipulation of the environment). This could be seen as a precondition for understanding iconic gestures. In order to understand an iconic gesture one has to process and later recognize the bodily action that is involved in an activity. The subject would be familiarized with two different ways of operating the apparatus to retrieve a reward. Once the apparatus has been operated in one way, this option would be blocked. In a competitive setup, one subject would observe a conspecific operating an apparatus in one way. The subject could not see the actual manipulation of the apparatus, but only the body movement associated with it. Then the subject would be given the opportunity to operate the apparatus. The critical point would be, whether the subject would choose the option not chosen by the conspecific.

(5) To investigate the limits of recognizing iconicity, children could be confronted with gestures that vary with respect to the similarity with the action they refer to. For example, the functional attachments of set B ('PUSH-IN') and C ('TURN-CRANK') could be used. In the beginning the same gestures as used in this study would be used. Given that the child understands the iconic gesture, after a few trials the experimenter would use his head to refer to one of the apparatus (moving it back and forth to refer to the pushing in; making a circular motion to refer to the turning of the crank). Thereby one could investigate to what extent a signal can be modified once a successful communication has been established. It would also be possible to administer these conditions the other way round (starting with the head gestures and moving on to the original gestures). In this way the degree of similarity necessary to recognize an iconic relationship could be approximated.

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APPENDIX



FIGURE A1.1. Photograph of the experimenter producing a gesture

GERMAN VERBAL INSTRUCTIONS FOR CHILD STUDY

Introduction

Instruction given upon entering the test room:

German: „Schau mal, hier sind ein paar Murmeln und weißt du was man mit den Murmeln machen kann? Man kann sie in diese Röhre machen und damit einen Turm bauen. Probier's doch mal aus! Sehr gut! Wenn man ganz viele Murmeln sammelt kann man den Turm bis ganz nach oben hin bauen. Willst Du das machen? Ich habe ein Spiel mitgebracht bei dem wir ganz viele Murmeln für den Turm sammeln können.“

(English: „Look, here we have some marbles and do you know what we can do with them? We can put them in the tube to build a tower. Try it! Very good! If you collect a lot of marbles you can build the tower up to the top of the tube. Do you want to do that? I brought a game with me in which we can collect a lot of marbles for the tower.“)

Training

Instruction before turning to one of the sides:

German: „Pass mal gut auf!”

(English: „Pay attention!”)

Instruction if the child did not automatically follow the experimenter’s turn:

German: „Komm her!”

(English: „Come here!”)

Instruction upon retrieval of the marble:

German: „Da ist die Murmel, ab in den Turm damit!”

(English: „There is the marble, put in the tower!”)

Test

Instruction between training and test trials:

German: „Wow, jetzt haben wir ja schon ganz schön viele Murmeln gesammelt, aber wir brauchen noch mehr um den Turm ganz voll zu machen. Hm... willst du noch mehr Murmeln sammeln? Wollen wir das Spiel einmal anders spielen?”

(English: „Wow, we have collected a lot of marbles, but we have to get more to finish the tower. Hm... do you want to collect more marbles? Do you want to play the game differently?”)

Instruction before each test trial:

German: „Pass mal gut auf,... Lass uns mal die Murmel holen).”

(English: „Pay attention,... Let’s get the marble!”)

Instruction in case the child made a wrong decision and did not automatically correct it:

German: „Komm her, hier ist die Murmel.”

(English: „Come here, the marble is here.”)

Instruction in case the child did not make a decision in the first three trials of each condition;
accompanied by simultaneous pointing to both sides:

German: „Entweder hier oder hier.”

(English: „Either here or here.”)

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ABSTRACT (GERMAN)

Diverse Theorien zu den evolutionären Ursprüngen der menschlichen Kommunikation betonen die Bedeutung von ikonischen Gesten als wichtiges Kommunikationsmittel im Übergang von primaten-typischer zu spezifisch menschlicher Kommunikation (Armstrong & Wilcox, 2007; Tomasello, 2008). Ikonische Gesten sind Körper und/oder Handbewegungen die ihrem Referenten ähneln. Sie ermöglichen eine reichhaltige, „natürliche“ Kommunikation über perzeptuell abwesende Entitäten ohne dabei auf Kommunikationsnormen zu basieren. Wenig ist jedoch bekannt über die evolutionären Ursprünge dieser Gesten. Einige Beobachtungsstudien an Menschenaffen berichten sowohl von Verständnis als auch von Produktion von ikonischen Gesten (Tanner & Byrne, 1996; Pika & Mitani, 2004, 2006). Es ist jedoch unklar in wie fern diese Gesten aufgrund ihrer Ikonizität verstanden werden.

Auf der anderen Seite zeigen experimentell Studien, dass menschliche Kinder ikonische Gesten ab ihrem zweiten Lebensjahr produzieren und auch verstehen (Behne, Carpenter & Tomasello, 2010; Namy, 2008). Es ist jedoch unklar in wie fern Kinder ikonische Gesten anders wahrnehmen als arbiträre Gesten. Möglicherweise Verfügung Kinder über eine generelle Fähigkeit zur Symbolisierung, welche auf jedes potentielle Kommunikationsmittel angewandt wird. Um diesen Fragen nachzugehen wurden Schimpansen (*Pan troglodytes*) und vierjährige Kinder (*Homo sapiens*), hinsichtlich ihrer Fähigkeit ikonische und arbiträre Gesten in einer Entscheidungssituation als Hinweise zu nutzen, untersucht.

Insgesamt nahmen elf Schimpansen und vierundzwanzig vierjährige Kinder an der Studie teil. Jede/r ProbandIn durchlief zwei Experimentalbedingungen (ikonisch und arbiträr), wobei deren Reihenfolge über die ProbandInnen hinweg ausgeglichen verteilt wurde. Die Aufgabe für die ProbandInnen bestand darin, sich zwischen zwei Alternativen (Orten) zu entscheiden, von denen nur eine belohnt wurde. Als Hinweis, welcher Ort belohnt würde, wurde jeweils eine Geste verwendet. Die Beziehung zwischen Geste und angezeigtem Ort war je nach Bedingung entweder ikonisch oder arbiträr. Die ikonische Beziehung wurde durch die Anwesenheit einer Apparatur am jeweiligen Ort hergestellt. Die Bedienung der Apparaturen erfolgte gemeinschaftlich zwischen ProbandIn und Versuchsleiter. Dabei wurde die Bewegung, welche zur Bedienung der Apparatur

notwendig war als Geste verwendet (z.B.: ‚ein Seil herunterziehen‘ oder ‚einen Hebel eindrücken‘). In der arbiträren Bedingung war keine solche Beziehung vorhanden. Beide Spezies wurden mit demselben Versuchsaufbau und denselben Apparaturen getestet. Dabei wurde kodiert ob die von der/m ProbandIn gewählten Alternative mit der durch die Geste angezeigten übereinstimmte. Pro Bedingung erhielt jede/r ProbandIn 24 Durchgänge. Um das Verhalten der Schimpansen über einen längeren Zeitraum hinweg zu untersuchen, erhielten diese zusätzliche Durchgänge.

Zur Datenauswertung wurde ein ‚generalized linear mixed model‘ (GLMM) verwendet. Die Ergebnisse zeigten, dass die ProbandInnen besser abschnitten, wenn sie die ikonische vor der arbiträren Bedingung erhielten (Haupteffekt für Reihenfolge: $\beta = 0.66 + 0.22$, $z = 2.987$, $p = 0.003$). Dies impliziert, dass ikonische, nicht aber arbiträre, Gesten dabei helfen eine kommunikative Interaktion herzustellen. Des Weiteren schnitten Kinder in der ikonischen Bedingung besser ab, verglichen mit ihrer eigenen Leistung in der arbiträren Bedingung und der gesamten Leistung der Schimpansen (Interaktion von Spezies und Bedingung: $\beta = 0.77 + 0.33$, $z = 2.37$, $p = 0.02$). Dies deutet darauf hin, dass Kinder, nicht aber Schimpansen, ikonische, nicht aber arbiträre Gesten unmittelbar als kommunikativ wahrnehmen können. Die Analyse der Leistung der Schimpansen über die Zeit hinweg zeigte, dass diese ein bestimmtes Leistungsniveau schneller in der ikonischen als in der arbiträren Bedingung erreichten (Wilcoxon Signed Ranks Test, $Z = -2.201$, $p = 0.031$).

Diese Ergebnisse zeigen, dass Kinder und auch Schimpansen Zugang zu ikonischer Information in Form von Gesten haben. Nur Kinder sind jedoch in der Lage ikonische Gesten unmittelbar als Kommunikationsmittel zu verstehen. Darüber hinaus scheinen arbiträre Gesten ungeeignet dafür zu sein, eine kommunikative Interaktion zu initiieren.

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