A challenging issue in the comparative and developmental literature concerns the effort to define and describe the underlying nature of concepts and representations. This volume represents an attempt to define perception, and what it might mean for an organism to have a “theory of perception.” Typically, if an organism is able to differentiate between different objects, making operational choices between them, that organism is said to have an understanding of the objects’ different properties, or at least to have discriminated between them in a meaningful way. If the organism can predict that different objects will have differential effects on the world that organism may be said to have some limited causal understanding. Adding complexity to the study of such topics is the issue of implicit versus explicit levels of understanding. To act on objects in the world in meaningfully different ways is not necessarily functionally equivalent to reflecting on those objects, or one’s own actions, in a conscious or metacognitive manner.

As evolutionary psychologists, our focus has been to understand how our closest living relatives may be both similar to and different from humans in their approach to solving social and physical problems. We have previously proposed that one critical way in which non-humans, even the other apes, may differ from humans, is in their ability to represent and reason about unobservables (Povinelli, 2004; Vonk and Povinelli, 2006). We posit that to have a true “theory” of objects or other organisms (whether it be a theory of perception or a theory of mind), an organism must represent...
properties of objects as being inherently tied to that object, whether that organism is
currently perceiving that object and its effects or not, and whether those properties are
available to the senses or are unobservable but inferred properties. Thus, in our work,
we have chosen to explore chimpanzees’ understanding of the mental state of seeing in
the social realm, and physical states such as weight (which is tied to objects but not
perceived when objects are not currently being lifted) in the physical realm. In what
follows, we discuss the effects of rearing environment on chimpanzees’ abilities to form
causal “theories” in these domains.

Theorists from multiple disciplines have become increasingly interested in the ques-
tion of how uniquely human rearing practices affect a child’s cognitive development
(Astington, 1996; Bard and Gardner, 1996; Brown, Collins, and Duguid, 1989; Harlow
and Harlow, 1965; Lave and Wenger, 1991; Lewis and Rosenblum, 1975; Russon,
1990; Tomasello, 1999). Social constructivists, such as Vygotsky (1962, 1978), argued
that a child’s (specifically human) intellectual development depends upon immersion in
human culture, a fundamental component of which is engagement in social learning
practices and verbal communication with other beings. More recently, Call and
Tomasello (1994, 1996) have argued that the experience of being engaged in triadic
social interactions, in which the human child is treated as an intentional being by other
humans, is critical for the development of particular cognitive abilities, such as the ability
to represent and reason about mental states (i.e., theory of mind; see also Tomasello,
1995, 1999; Tomasello, Kruger, and Ratner, 1993; Tomasello, Savage-Rumbaugh, and
Kruger, 1993). Of course, a range of views on the plasticity of human cognition exist,
including strong nativism (Fodor, 1986), starting state nativism (Gopnik and Meltzoff,
1997), and representational re-description (Karmiloff-Smith, 1992).

For Vygotsky (1978), the human social and cultural environment fostered an
expansion of cognitive abilities in human children, which was possible only by virtue of
the uniquely human biological prepotency for such abilities. Later social constructi-
vists, in contrast, have argued that these same rearing experiences, when directed
toward our closest living relatives (the great apes), can lead to the development (or
extensive elaboration) of at least certain aspects of what were previously thought to be
uniquely human abilities, such as theory of mind (Call and Tomasello, 1994; 1996). Of
course, the ability to represent mental states is only one among several psychological
capacities that may turn out to be uniquely human, and that may be affected by the
human rearing environment (see Povinelli, 2000; Bering, Bjorklund, and Ragan,
2000). Determining whether these abilities can be fostered in other species, and to
what extent, is an important avenue for exploring the plasticity of psychological
development in both humans and other species. It is also a vital method for setting
limits on the nature of the uniqueness of human psychological specializations.

A range of more specific hypotheses regarding the role of human-rearing on
cognitive development in non-human apes have been proposed (Bering et al., 2000;
Call and Tomasello, 1994, 1996; Carpenter, Tomasello, and Savage-Rumbaugh,
1995; Donald, 2000; Gardner and Gardner, 1971; Hayes and Hayes, 1951; Leavens

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and Hopkins, 1998; Miles, 1990; Russon and Galdikas, 1993; Savage-Rumbaugh, McDonald, Sevcik, Hopkins, and Rubert, 1986; Tomasello, 2000; Tomasello, Kruger, and Ratner, 1993; Whiten, 1993). Perhaps the strongest of these claims, labeled the “enculturation hypothesis,” is an extension of social constructivist theory to other species. In this analysis, human rearing substantially alters the cognitive systems of young apes such that they develop psychological abilities never expressed in their wild counterparts, or other apes who, although they interact with humans on a daily basis, are primarily reared with each other (Bering et al., 2000; Tomasello, Savage-Rumbaugh, and Kruger, 1993b). Human rearing practices directed toward these apes are seen as leading to the development of psychological abilities otherwise uniquely human (Call and Tomasello, 1996; Donald, 2000; Premack, 1983; Tomasello, Kruger and Ratner, 1993). Conversely, Suddendorf and Whiten (2001) argue that, although rearing environment guides the ape’s cognitive development, human rearing practices may merely function to restore the species-typical pattern of development normally disrupted with more typical captive rearing environments. They have suggested that the “special” abilities sometimes attributed to only human-reared apes may in fact be shared with apes reared by their natural mothers in the wild.

A more moderate version of the “enculturation hypothesis” posits that human-reared apes will differ only in certain specific domains or abilities, such as the ability to reason about mental states (for example, the intentions of another; Bjorklund and Pellegrini, 2002; Call, Agnetta, and Tomasello, 2000; Call and Tomasello, 1996; Miles, 1990; Tomasello, 1999; Tomasello and Call, 2004; Tomasello and Camaioni, 1997, or communicative abilities; Lyn, Russell, and Hopkins, 2010). Proponents of this moderate hypothesis predict that the effects of the environment have a more narrowly focused impact. They share with modularity theorists at least the idea that certain abilities can develop independently from other cognitive structures or domains (cf. Baron-Cohen and Swettenham, 1996; Fodor, 1986; Leslie, 1994; Scholl and Leslie, 1999; Segal, 1996).

A third hypothesis suggests that the core cognitive systems of human-reared apes do not differ at all from other chimpanzees, but that they develop a greater breadth of skill sets for coping with human social and material culture (Bering, 2004; Bjorklund, Yunger, Bering, and Ragan, 2002; Call and Carpenter, 2003; Call and Tomasello, 1996; Povinelli, 2000). In other words, the human rearing experience would not lead to any fundamental change in their conceptual systems, but instead would lead to the accretion of a different skill set. This general hypothesis has also been instantiated in both broadly and narrowly focused forms. For instance, Bering (2004) focused on the human-reared apes’ extensive experience with the manipulation of objects, whereas Tomasello and Call (2004) point to the human-reared apes’ social skills, namely the ability to represent the intentions of other beings.

All of these and other more specific hypotheses concerning the effects of early experience on psychological development in apes can be tested by comparing apes reared under various environmental conditions. Researchers have not yet taken full
advantage of such opportunities. Chimpanzees are the ideal participants for such studies. First, they are arguably the closest living relatives of modern humans (Jensen-Seaman, Deinard, and Kidd, 2001; Pennisi, 2002; Ruvolo, Zehr, Goldberg, Disotell, and von Dornum, 1994). Second, they are perhaps the best-studied of all great apes, with a reasonable corpus of data dating back to the turn of the previous century. Finally, large numbers of socially enriched chimpanzees, reared in a variety of ways, currently exist in the United States and elsewhere. The range of such early experiences is impressive, and includes (a) chimpanzees who have been (or are currently being) reared in human homes as “foster children” (for examples, see Appendix), (b) chimpanzees reared with chimpanzee peers with extensive human contact, (c) chimpanzees reared by chimpanzee mothers in sanctuaries in African countries such as Liberia, and (d) chimpanzees reared in captivity by their chimpanzee mothers. This range of early rearing histories allows for a large-scale test of the hypothesis that human-rearing leads to fundamental changes in cognitive development in this species. Properly conducted, such a long-term study could address historical questions concerning the malleability of chimpanzee cognitive development, and the biological disposition for human cognition (see also Bering, 2004; Lyn et al., 2010; Povinelli, 1996b, 2000; Suddendorf and Whiten, 2001).

The studies reported here were conducted as part of a feasibility project to determine whether one critical group of participants (human-reared chimpanzees) could be suitably adapted to the study procedures necessary for the comparisons described above, as well as to obtain some preliminary data on social and physical reasoning in these participants. These feasibility studies were conducted as a prelude to a large-scale project that could be developed. A critical component of this larger project is the ability to compare chimpanzees from various rearing backgrounds in an identical testing environment using identical procedures. We report the results of four studies that explored the ability of three human-reared chimpanzees to reason about the visual perspective of others (one well-studied component of the human theory-of-mind system), as well as their understanding of certain physical interactions in the context of simple tool-using problems. These studies were designed to carefully match the general procedures of previous studies involving peer–raised chimpanzees (see Povinelli, 2000; Povinelli and Eddy, 1996a, 1996b; Reaux, Theall, and Povinelli. 1999).

Study 1: Understanding of Visual Attention I

In Study 1, we assessed three human-reared chimpanzees’ understanding of visual attention using procedures developed in our laboratory (and replicated elsewhere) with peer-reared chimpanzees (Kaminsky, Call, and Tomasello, 2004; Povinelli and Eddy, 1996a; Reaux et al., 1999), to determine whether human-reared chimpanzees exhibit a heightened sensitivity to more subtle indicators of visual attention. The participants were required to use a species–typical, visual gesture to request a treat from one of two human experimenters, one of whom could see them and another who could not.
Method

Participants Participants were three juvenile chimpanzees who had been raised by human surrogate parents from about six weeks of age. Two of the participants (03 and 02) were females (41 and 62 months, respectively) and one (04) was male (73 months). The participants were selected after documenting their extensive history of human-rearing and immersion in human social and material culture (see Appendix for details). All applicable federal and State regulations were followed in the testing of the participants, and the research protocols were approved by the University of Louisiana Institutional Animal Care and Use Committee (approval numbers: 2003-8717-015). The participants and their surrogate parents traveled to Lafayette, Louisiana, and during the day, were guests of the University and were accommodated in a 4,000 square ft residence dedicated for this purpose. At night, they provided their own accommodations or stayed at the guest house. They participated in the study over a period ranging from four to nine days.

Figure 1. A depiction of the test arena.
Procedure General Orientation. Several rooms of the residence were dedicated to the testing of the participants (a suite of warm-up rooms, a study room, and a video control room). For a period of one to three days, the participants were adapted in the context of free play to the warm-up and study room as well as to the materials to be used in various studies. The study room contained a spacious testing arena, enclosed in front by a large, transparent partition, containing two large response holes through which the participants could reach (see Figure 1). Once the participants were comfortable in these environments, they began training.

Training. Participants underwent a training phase in which they were acclimated to the test arena and encouraged to gesture to a single experimenter through the holes in the partition for a food reward before testing began. Before each trial, a single experimenter was seated approximately 100 cm in front of one of the two response holes, at a height designed to be close to eye-level with the participants. The left/right position of the experimenter was randomized in blocks of four trials, with the constraint that an experimenter was not seated on the same side for more than two consecutive trials. Within a block of four trials, two different individuals served as experimenter twice each, once on each side of the test arena (in a random order). On all trials, the experimenter fixed their gaze on a pre-determined location directly above the response hole in front of her, so as to be looking where the chimpanzee would gesture, without making direct eye contact. The trainer then brought the chimpanzee to the rear entrance of the test arena, to a point equidistant between the two response holes. The trainer released the participant into the testing arena, thus allowing the participant to approach the partition and gesture. If the participant gestured through the correct hole, the experimenter praised the participant, and handed him or her a food reward. The food reward was originally held out to the participants, subsequently placed within view of the participants, and ultimately placed out-of-sight behind the experimenter’s back. A gesture was considered to have been made as soon as the participant’s wrist broke the plane of one of the two response holes. If the participant gestured through the wrong hole, or did not respond within 30 seconds, the trainer was signaled (via an earpiece) from the video control room to call the participant back to the starting position, and the participant did not receive a reward. In order to advance to testing, the participants were required to execute 6 consecutive correct trials without any prompting from the trainer.

Testing. For participant 02, testing consisted of seven 12-trial sessions (always beginning with a standard trial) in which standard and test trials alternated. Standard trials were identical to those used in training. Within each session, each of two experimenters participated in 3 standard trials in random order, with one experimenter seated on the left twice and on the right once, and the other seated on the right twice and on the left once. Each session included one test trial of each of the six experimental conditions depicted in Figure 2, with the trials occurring in random order. For the test trials, each experimenter served as the correct experimenter three times and as the incorrect
experimenter three times, with the left/right position of the correct and incorrect experimenter counterbalanced within each session. The identity of the correct and incorrect experimenters and their left/right positions were also counterbalanced across the experiment within each type of test trial.

For participants 03 and 04, testing initially consisted of 12-trial sessions in which each session consisted of four standard trials (trials 1, 4, 7, and 10) and eight test trials (trials 2, 3, 5, 6, 8, 9, 11, and 12). After two sessions of testing for 04, and one testing session for 03, a decision was made to increase the ratio of standard trials to test trials to maintain motivation. From that point forward, sessions consisted of six trials. Trials 1, 2, 4, and 6 were standard trials and trials 3 and 5 were test trials. Each experimenter

Figure 2. A depiction of the conditions presented to the chimpanzees in the test trials of Study 1. From top left to bottom right; “eyes open/closed,” “blindfolds,” “screens,” “front/back,” “looking over shoulder,” “attending/distracted”
participated in two standard trials per session, once on the left and once on the right, in random order. The six test conditions were presented in random order across sessions with side location and identity of the correct experimenter counterbalanced within each test trial type across sessions. Each condition occurred once before any repeated. Each condition was presented a total of six times for a total of 36 test trials for each participant.

**Data Coding**

For all of the studies reported here (Studies 1–4), two coders independently viewed all trials from the video records, and scored whether the participants’ first choices were correct. Inter-rater reliability was perfect for all measures in all studies (Cohen’s kappa’s = 1).

**Results and Discussion**

The participants adapted rapidly to the environment, and were easily trained to gesture to the experimenters through the response holes. They required only 9 to 14 trials to meet criterion, in contrast to the lengthy training required by the previously tested peer-reared chimpanzees (see Povinelli and Eddy, 1996a).

In testing, the participants maintained a high level of performance on the standard trials (which were identical to those used in training). Participant 02 gestured correctly on 39/42 (92.8%) of the standard trials, and participants 03 and 04 gestured correctly on all 64 and 68, respectively, (100%) of their standard trials (binomial tests, \( p < .001 \) in all cases). These results are important, because they demonstrate that the participants were highly motivated and were attending across the entire testing phase.

The critical results of the testing phase concern the participants’ performances on the embedded test trials, and these results are presented in Table 1. The results reveal that none of the participants performed at levels exceeding chance in their first session (although Participant 02 did perform 5/6 (83%) of her test trials accurately), nor did their overall responses (within any of the individual conditions) exceed chance. Participant 02’s performance in the “looking-over-shoulder” and “front/back” conditions approached significance (\( p = .06 \), binomial test). Finally, there was no evidence of learning across sessions (see Table 1).

The chimpanzees in this study were juveniles (3–6 years), but their ages are comparable to that of the peer-reared apes who participated in the studies that the present work replicates (those chimpanzees were 4–5 years when training began, and 5–6 years when testing ended; see Povinelli and Eddy, 1996a). Those peer-reared chimpanzees performed at levels exceeding chance from trial one forward in the “front/back” condition, but not the other conditions used here (although they did learn to do so across 8 to 20 trials, depending on participant and condition; see Povinelli and Eddy, 1996a). Interestingly, in the present study, for two of the participants (02 and 03), body orientation (i.e., “front-versus-back”) appeared to be more
salient than presence of the face (i.e., “screens”) or the presence or absence of the eyes (“eyes open/closed” and “blindfolds”). Thus, the results from these human-reared chimpanzees appears similar to those from the peer-reared chimpanzees in that body orientation was the most salient feature in determining to whom they directed their visually based gesture. Longitudinal studies of the peer-reared chimpanzees revealed no evidence of improved performance in experiments as they matured, and in fact they failed to retain much of what they learned in the early studies (see Reaux et al., 1999). It is possible that the human-reared apes might show an improvement in performance with age that the peer-reared group did not. Certainly this limited sample suggests that, before the age of six, human-reared chimpanzees do not have a greater understanding

### Table 1. Trial by trial performance on test trials of Study 1 by participant and experimental condition. A “+” indicates that the participant chose the correct experimenter on that trial.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (months)</th>
<th>Trial Type</th>
<th>A/D</th>
<th>Eyes</th>
<th>L/O/S</th>
<th>B/Fold</th>
<th>F/B</th>
<th>Screens</th>
<th>Mean</th>
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<tr>
<td>03</td>
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<td>1</td>
<td>+</td>
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**Note.** A/D = attending versus distracted, Eyes = eyes open versus closed, L/O/S = looking over shoulder, B/Fold = Blindfolds, F/B = front/back. See Figure 2 for a depiction of the test conditions.
of the observable features of “seeing” compared to similarly aged peer-reared chimpanzees. Importantly, the results of the current study demonstrate the feasibility of acclimating home-reared chimpanzees to novel testing environments and completing data collecting within a short time period.

Study 2: Understanding Visual Attention II

In Study 1, there were salient visual cues (e.g. body orientation, presence of the eyes), as to the attentional states of the experimenters, and the chimpanzees were highly familiar with the significance of such cues in social interactions. In contrast, Study 2 created a context in which the participants, after having had extensive first-person experience wearing two buckets over their heads, could later infer, in the absence of behavioral cues, which of two humans (each wearing one of the buckets) would respond to their visual gestures (see Povinelli and Vonk, 2003; 2004). The important feature of the buckets was that, although the first person experiences when wearing the buckets were radically different (being able to see versus not being able to see out of the bucket), when viewed from a third-person perspective, they looked identical except for their color. The participants experienced the buckets from only a first person perspective prior to testing.

Method

Participants The three chimpanzees described in Study 1 also participated in this study. However, only Participants 02 and 04 took part in testing. Participant 03 was not tested because she did not spend the criterial amount of time experiencing the critical properties of both buckets during familiarization sessions (see below).

Materials Both buckets contained visors that appeared opaque from the outside; that is, an observer could not see the face of the wearer. However, one visor allowed the wearer to see out of the bucket (the blue bucket), and the other did not (yellow bucket).

Procedure Familiarization. Participants took part in three (for Participant 02) and seven (for Participant 04) free play sessions in which they interacted with the trainer and the buckets in the test arena for a minimum of five minutes per session. One session was conducted per day. The trainer encouraged participants to look inside of the buckets and placed the buckets over their heads but did not wear the buckets himself. It was critical that the participants obtained the first-person experience of wearing both buckets but did not observe another individual wearing the buckets prior to testing. Sessions continued until the investigators deemed that the participants had met a criterial amount of time interacting with the buckets.

Testing. The general procedure was identical to that described for Study 1. Testing sessions consisted of standard and test trials. Standard trials were the same as those
described in Study 1. On test trials, before the participant entered the testing arena, two experimenters positioned themselves as in Study 1, and then placed the buckets over their heads (and kept them in place until after the trial was over and the participant had exited the testing arena). Participant 02 participated in four 12-trial sessions in which standard and test trials alternated, always beginning with a standard trial, for a total of 24 test trials. On the test trials within each session, each experimenter wore each bucket an equal number of times, and each bucket appeared on each side an equal number of times. Within a session, one experimenter sat on the left four times during test trials and two times on the right, and the other sat on the right four times and on the left two times. Each experimenter participated in three standard trials, one experimenter sitting on the left twice and on the right once and the other sitting on the right twice and on the left once. This positioning of experimenters was counterbalanced across sessions. Participant 04 participated in eight 6-trial sessions, which followed the exact same counterbalancing procedure as in Study 1, for a total of 16 test trials. Side location and identity of the correct experimenter were counterbalanced within the first and last half of the total number of test trials.

Results and Discussion

The participants were extremely interested in the buckets and placed their heads inside them repeatedly (with occasional prompting from the trainer). They ambled about the testing arena with the buckets on their heads and when wearing the see-through bucket, looked through the visor at the environment and at the trainer, who made waving motions in front of their faces. When wearing the opaque bucket they moved about the test arena gingerly and examined the inside and outside of the buckets with their hands.

On the standard trials of testing, participants 02 and 04 correctly gestured on 24/24 (100%) and 32/32 (100%) trials, respectively (binomial tests, \( p < .001 \) in both cases). Again, these results demonstrate that the participants were attending and motivated throughout the testing phase.

The critical data from the test trials are presented in Table 2. Across testing, neither participant performed at levels exceeding chance (binomial tests, \( p = ns \) in both cases). Participant 03-002 performed at chance on her first session, and 66.7% correct on the following three sessions. Although this constitutes some weak evidence for learning by this participant, it would not uniquely implicate a first/third-person mapping given that after the initial trials, participants could learn to gesture to the experimenter wearing the blue bucket, without making the attribution that only that experimenter could see their gesture. In contrast, participant 04 exhibited no evidence of learning across trials, and instead demonstrated a strong person preference, selecting the same individual, regardless of which bucket she wore on 14/16 (87.5%) trials (binomial tests, \( p = .002 \)).

In summary, Studies 1 and 2 demonstrated the feasibility of quickly adapting home-raised chimpanzees to an environment in which their social cognition could be explored. At the same time, they provided some preliminary evidence that the performances of
such chimpanzees may not differ substantially from peer-reared chimpanzees (although this conclusion must be strongly tempered given the extremely small sample). In addition, this work demonstrates that more diagnostic procedures for testing the attribution of mental states (e.g., Study 2) can be conducted using these participants.

Study 3: Trap Table

Next, we report two studies exploring whether human-reared chimpanzees might perform differently from peer-reared chimpanzees on tasks related to an understanding of physical causality. Study 3 tested whether they understood that an object dragged across a surface interrupted by a large open space would fall into the open space, whereas an object dragged across a smooth, uninterrupted surface would travel across the surface to within reach. The procedures of this study were carefully designed to match those used previously with our peer-reared chimpanzees (see Povinelli, 2000, Chapter 5, Experiment 3).

Method

Participants and Materials Participants 03 and 04 participated in this study.

The two rake tools and table apparatus (94 × 85 × 46 cm) depicted in Figure 3 were constructed. The table apparatus was constructed so that it had two removable surfaces (each 92 × 41 cm), allowing for surfaces with different properties to be inserted. On familiarization and standard trials, two identical, solid surfaces were used. On testing trials, one of the testing surfaces had a large, rectangular hole (10 × 30.5 cm) cut into its center, hereafter described as “the trap,” through which food rewards would fall if the tool placed behind the food was pulled forward. The other testing surface possessed a painted blue rectangle of the same dimensions in the same relative position.

Table 2. Trial by trial performance on test trials of Study 2 by participant. A “+” indicates that the participant chose the correct experimenter on that trial.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (months)</th>
<th>Trial</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>62</td>
<td>1</td>
<td>– – + +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>– + + +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>– + – +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>+ – + –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>+ + + +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>+ + – –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>50 66.7 66.7 66.7</td>
</tr>
<tr>
<td>04</td>
<td>73</td>
<td>1</td>
<td>+ + + – – – – –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>– – – + + + + +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>50 50 50 50 50 50 0 50</td>
</tr>
</tbody>
</table>
Procedure Familiarization. For two sessions, the participants were released into the test arena and an experimenter demonstrated how to pull the tool so that the food reward would slide to within the chimpanzees’ reach.

Criterion. Participants entered the test arena to find a tool on one side of the table with a food reward placed directly in front of it. Each side of the table was aligned with one of the response holes cut into the partition so that the participant could reach through only one hole at a time to reach a tool. The side of the table on which the tool was placed varied randomly across trials, with the constraint that the tool appeared on the left twice and on the right twice within each block of 4 trials. Participants were given one minute from the time they entered the test arena to retrieve the reward. Trials continued until the participants successfully used the tool to obtain the food reward on four consecutive trials.

Testing. Testing consisted of a single 14-trial session. Eight of these trials were standard trials and were exactly the same as criterion trials. For 03, standard trials occurred as trials 2, 4, 5, 6, 8, 9, 11, and 14. For 04, standard trials occurred as trials 1, 2, 3, 6, 8, 9, 11, and 14. The left/right location of the tool on these trials was randomized within the constraint that it occurred equally often on each side. The remaining six trials were test trials, in which one side of the table contained the trap and the other side contained the painted rectangle. The left/right location of the two surfaces was determined randomly within the constraint that each occurred equally often on both sides. Identical tools and food rewards were placed directly behind the trap and painted rectangle on each side of the table before the participants entered the test arena. The handles of the tools were positioned so that the participants could not
pull both handles simultaneously. Participants were given one minute to respond from the time they entered the test unit. A choice was defined as grabbing the handle of one of the two tools. A trial was ended when the participant pulled on the tool in front of the “trap,” by the trainer remotely covering the response holes and calling the participant to exit the test arena. If the participant pulled on the correct tool, the trial was ended as soon as he or she had retrieved the reward and before they could make a second choice. However, on the first test trial for both participants, they initially chose the correct tool and retrieved a reward, but subsequently pulled in the incorrect tool and saw the reward fall into the trap before the response holes were covered.

Results and Discussion

Across the familiarization and criterion phases, participants 03 and 04 received 8 and 19 trials, respectively, before reaching criterion.

In testing, both participants successfully retrieved the food reward on all standard trials (again indicating a high degree of attention and motivation). The critical data concerns their performance on the test trials, and these are presented in Table 3. Participant 03 was correct on only 2/6 (33.3%) test trials, and participant 04 was correct on 4/6 (66.7%) test trials (binomial tests, \( p = \text{ns} \)). Neither participants’ choices were the clear result of a side bias, nor was there any evidence of learning across trials.

These results again revealed rapid acquisition to the testing procedures and little in the way of differences from the peer-reared chimpanzees previously tested (Povinelli, 2000, Chapter 5, Exp. 3). Indeed, one of the peer-reared chimpanzees from the previous investigations, performed at levels exceeding chance from Trial 1 forward (see Povinelli, 2000, Chapter 5, Exp. 3). The experience of human rearing thus did not seem to engender any special skills in these animals with respect to their abilities to anticipate the consequences of pulling the food reward toward the trap.

Girndt, Meier, and Call (2008) have suggested that it is easier for apes to succeed in the trap–table problem when presented with only a single tool, which they are allowed to position themselves, rather than being asked to choose between two tools—one being positioned in front of the trap and the other not. However, their series of experiments presented various other confounds concurrently along with the manipulation of number of tools presented, and the apes accumulated experience in the task as the experiments went along so it is difficult to ascertain precisely what component of

Table 3. Trial by trial performance of participants in the test trials of Study 3. A “+” indicates a correct choice. A “−” indicates an incorrect choice.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (months)</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
<th>Mean %</th>
</tr>
</thead>
<tbody>
<tr>
<td>03</td>
<td>41</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>33.3</td>
</tr>
<tr>
<td>04</td>
<td>73</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>66.7</td>
</tr>
</tbody>
</table>
the task engendered success. What their experiments did show is that apes may be very limited by particular task constraints and thus, their problem-solving may not be flexible. Similarly, Seed, Call, Emery, and Clayton (2009) found that chimpanzees had greater success solving the trap-tube problem when the tool was not inserted in the tube at the onset of the problem. Thus far, our limited sample size does not suggest that enculturation confers any greater flexibility in problem-solving with regards to tool use.

**Study 4: Rigid versus Flimsy Tool**

Study 4 also examined the participants’ understanding of physical interactions using previously developed procedures (Povinelli, 2000, Chapter 7, Experiment 9). In this experiment, they were required to reason about the affordances of two tools made out of visually similar but tactiley distinct materials. One tool was made of rigid material (wood) and the other was made of malleable (flimsy) material (rubber). Only the rigid tool could be used as a rake to drag a food reward to within reach across the surface of a table.

**Method**

*Participants and Materials* The two chimpanzees who participated in Study 3 also participated here. The table apparatus from Study 3 was also used, but exclusively with the solid surfaces from standard trials installed. Three rake-tools, with identical handles as those used in Study 3 were constructed. Two of the tools contained a wooden, rigid base (4 x 41 cm); the base of one of these tools was painted red and was used in the familiarization and criterion phases and standard trials during testing; the base of the other tool was painted grey, and was used in test trials during testing. The remaining tool was also used in test trials during testing. It was of identical dimensions as the others, but its base was constructed from a highly pliant strip of rubber. The testing tools are depicted in Figure 4.

*Procedure*

**Familiarization.** In order to familiarize them with the properties of the specific materials to be used (outside of the experimental context), the participants were given three free play sessions in the test arena (ranging from 5 to 20 minutes each) in which they interacted with the tools in the presence of the trainer. The trainer encouraged them to pick up and manipulate the tools, which they did, using their hands and mouths.

**Criterion.** Before the participant entered the test arena, the experimenter entered and seated herself on a crate behind the table. Once the chimpanzee entered the test arena, the experimenter held the training tool upright, and then positioned it on one side of the table with the handle of the tool placed just within reach of the chimpanzee. The side location of the tool was randomized across trials with the constraint that, within every block of four trials, the tool appeared on the left twice and on the right twice.
The tool did not appear on the same side for more than two consecutive trials. After positioning the tool, the experimenter held up the food reward and placed it inside the left corner of the tool. She then exited the test arena. Five seconds after her exit, a transparent barrier was lowered exposing the holes in the partition through which the chimpanzee could reach to gain access to the tool. The chimpanzee was given one minute from the time the barrier was lowered to reach through the response hole aligned with the tool in order to pull it in to retrieve the food reward. Trials continued until the participants successfully received a food reward on four consecutive trials.

Testing. Testing consisted of three 6-trial sessions. Four of these trials (trials 1, 2, 4, and 6) were standard trials, and were identical to the criterion trials. The left/right location of the tool on these trials was randomized within the constraint that it appeared on the left twice and on the right twice within a session. The remaining two trials were test trials. On test trials, once the ape was in the arena and attending, the experimenter demonstrated the properties of each of the tools by holding the tool upright and tapping three times on each side of the base of each tool, before placing it on the table, always beginning with the tool on her left and demonstrating with each tool for an equivalent amount of time (three seconds). The experimenter then simultaneously placed the food rewards inside the left-hand corner of each tool, and
after doing so, left the room. Following a five-second count and a signal from the video control room, the trainer then remotely opened the response holes, allowing the chimpanzee to choose a tool. A choice was defined as grabbing one of the tools. A trial ended with the barrier being raised to cover the response holes and the participant being called by the trainer, as soon as he or she pulled in the incorrect tool or pulled in the correct tool to retrieve a reward. The chimpanzees always responded before the one minute time limit expired. The left/right location of the tools on test trials was randomized across sessions within the constraint that the correct tool appeared on each side three times.

Results and Discussion

Both participants required nine trials to reach criterion and, as in the previous studies, both successfully retrieved a food reward on all standard trials during testing.

The results from the critical test trials are presented in Table 4. Participant 03 was correct on only 3/6 trials (50% correct, binomial tests, \( p = ns \)). In contrast, participant 04 made only a single mistake (5/6 or 83.3% correct, binomial tests, \( p = ns \)), which occurred on the first test trial of his first test session. It appeared that this participant either entered the study with an appreciation of the functional affordances of the tools given their distinct properties, or demonstrated single-trial learning after observing the flimsy tool fail to bring in the food reward on the first test trial. We had encountered a similarly impressive performance on this task by one of our seven peer-reared chimpanzees (see Povinelli, 2000, Chapter 7, Experiment 9). However, in follow-up tests designed to probe that chimpanzee’s understanding of the affordances of the different tool materials (Povinelli, 2000, Chapter 7, Experiment 10) she performed at chance. Therefore, we decided to administer the same follow-up test (see below) to Participant 04 to further probe his understanding of the relation between the tool’s properties and their affordances in this task.

### Study 4a: Flimsy versus Rigid Tool Follow-Up

To explore whether Participant 04 understood that it was the rigid nature of the correct tool that assisted him in pushing a food reward forward across a smooth table surface, we constructed two tools identical to that used in Experiment 4 except that, on
One side of the handle, the tool portion was constructed out of wood and, on the other side of the handle, the tool portion was constructed out of pliable rubber (i.e., a “hybrid tool”). Both sides of the tools were colored gray as before. Test trials involved a choice between two of these identical tools oriented differently. If the participant understood that it was the properties of the material the tool was constructed from that either aided or impeded his performance in Experiment 4, he should correctly choose a tool that was oriented in such a way that the food reward was placed in front of the rigid portion of the tool.

**Method**

*Participant and Materials* Participant 04 was the sole participant of this study. The table apparatus used in Studies 3 and 4 was used with identical solid inserts installed. Two “hybrid” flimsy-rigid tools described above were constructed for use on test trials. The tool used in the standard trials of testing for Study 4, was used in the standard trials of this study as well.

*Procedure*

The participant was given a single 5-minute session of free play in the test arena with the trainer, in order to introduce him to the new “hybrid” tool to be used in testing. The experimenter manipulated both sides of the base of the tool when the participant was attending, and encouraged the participant to manipulate the tool himself. Given his performance in Study 4, a criterion phase to establish competence with the standard (rigid) tool was deemed unnecessary.

The testing procedure was identical to that of Study 4, with the following exceptions. On test trials, the two identical “hybrid” tools were used, one placed on each side of the table. A food reward was placed directly in front of the left-side base of each tool. The orientation of the tools was varied, however, so that either the flimsy, rubber side of the tool or the rigid, wooden side of the tool was in front of the food reward (see Figure 5). Thus, on each trial, there was an option of pulling a tool which could retrieve the reward (food against rigid base) versus one that could not (food against flimsy base), even though the tools were the same. The left/right location of the tool orientations were randomized within the constraint that each orientation occurred equally often on each side of the table.

*Results and Discussion*

The participant successfully retrieved the food reward on all standard trials during testing, suggesting the same level of motivation and interest as in Study 4. In contrast, he was correct on 4/6 (66.7%, binomial tests, \( p = ns \)) of the critical test trials. He was incorrect on the first probe trial. The data indicate an intriguing intermediate-level performance (see Table 4), but additional testing with this and other participants are clearly needed. The only previously tested peer-reared participant who succeeded on a version of the flimsy versus rigid tool task had performed at chance when presented
with the “hybrid” tool (see above). One possible explanation for both apes’ performances is that they chose correctly in the initial experiment because they had some aversion to the flimsy tool, not because they appreciated the properties of the object that allowed for successful retrieval of the food reward.

Our results stand in contrast to the conclusions of Furlong, Boose, and Boysen (2008), who replicated Povinelli’s experiments with a group of what they described as “enculturated” and “semi-enculturated” chimpanzees. These researchers suggested

Figure 5. “Hybrid” tool used in testing trials of Study 4a. One side of the base of the tool is wooden and “rigid.” The other side is rubber and “flimsy.”
that enculturated apes succeeded in choosing the rigid rather than the floppy tool, while semi-enculturated apes showed an “intermediate” level of performance. However, they did not report first trial performance, so learning could not be ruled out. Although three of the enculturated chimpanzees were perfect on this task, the authors themselves acknowledge that only the rigid tool appeared similar to the training tool and so they may have simply continued to use the tool that they had been “primed” and reinforced for using previously. In addition, the researchers conducted a follow-up study to rule-out the use of perceptual features that differed between the tools and there was a significant drop in performance for all but one of the apes tested (Sheba). This decline in performance suggests the apes were not reasoning about the functional properties of the materials but instead were basing their choices on some visual cue linked to training. Moreover, it should be noted that the enculturated apes in the Furlong et al. studies were not only human-reared but also experienced laboratory subjects, so perhaps the combined experience with human objects and experimental testing led to their high levels of performance on this task.

Furlong et al. (2008) also conducted the hybrid tool task with mixed results. One of the enculturated apes performed perfectly on this task but none of the other apes were above 75% correct (only 3 of 14 apes tested performed at 75%). Again it is not possible to evaluate any effects of learning based on the information presented. So, while it appears that one enculturated chimpanzee evidenced an understanding of the properties of the tool used to rake in food rewards, this result could just as easily be attributed to individual differences as to any particular rearing history.

**General Discussion**

These preliminary studies can provide only limited insight on the question of whether the cognitive abilities of human-reared chimpanzees might differ in some important and previously undetermined ways from those of mother or peer-reared chimpanzees. Although the studies reported here were constructed to closely approximate past research conducted on peer-reared chimpanzees in our laboratory (Povinelli, 2000; Povinelli and Eddy, 1996a; Reaux et al., 1999), the sample of apes is too small, and the breadth of procedures too narrow, to draw any firm conclusions regarding the effects of various rearing environments on chimpanzee cognitive development. Our preliminary findings do not suggest any overt differences in their approach to the tasks presented here. Future research will determine whether differences do exist in cognitive domains not yet explored, or may emerge later in development than we could ascertain within this sample.

In fact, although there are a few very interesting and suggestive experimental reports comparing the abilities of human-reared to peer-reared chimpanzees (Call et al., 2000; Call and Tomasello, 1994; Furlong et al., 2008; Tomasello et al., 1993b), and orangutans (Call and Tomasello, 1995, 1998; Tomasello, Call, and Gluckman, 1997), those studies have always been constrained to very small sample sizes (1–9 apes from each rearing background) and have typically involved subjects from single laboratories,
tested on a single task. Furthermore, the conclusions from these studies have been mixed and open to interpretation (see critique by Bering, 2004). Early support for the enculturation hypothesis rested predominantly on the finding that human-reared chimpanzees might show a superior capacity for imitation relative to their peers (Tomasello, Savage-Rumbaugh, and Kruger, 1993) and that one human-reared orangutan demonstrated a better understanding regarding human pointing behaviors compared to one of his peers (Call and Tomasello, 1994). Importantly, the enculturated orangutan had also undergone more explicit training to comprehend and produce such gestures (Miles, 1990). Thus, it is difficult to determine whether it is more than a different training regime that leads to the differential performances of apes with varying experimental histories. In support of this supposition, a related study by Tomasello et al. (1997) revealed that the same enculturated orangutan responded more appropriately to human gestures he was already familiar with, but did not show a superior ability to learn novel signs relative to his non-enculturated peers (see also Call and Tomasello, 1998). He also passed certain control tasks more readily than non-enculturated orangutans and chimpanzees, but fared no better than them on the critical false belief tasks (Call and Tomasello, 1999). Call et al. (2000) concluded that enculturated apes might understand communicative intentions better than their peers but they still fail to demonstrate any appreciation of different knowledge states in other individuals. Notably, Tomasello and Call (2004) have recently come to believe that non-enculturated chimpanzees might display greater social-cognitive abilities than previously attributed to them, (although this conclusion is debatable; Povinelli and Vonk, 2003; 2004), thus diminishing their emphasis on the importance of human culture in altering the cognitive development of apes. Recently, Buttelmann and colleagues (Buttelmann, Carpenter, Call, and Tomasello, 2007) have suggested that enculturated chimpanzees can imitate rationally, implying an ability to infer the goals of the demonstrator, whereas non-enculturated apes are likely to emulate rather than imitate, further suggesting important differences in mental state attribution based on rearing histories. Obviously, any conclusions drawn from the existing data base must be tempered by its paucity.

The primary contribution of the current studies is their value as a tool to assess the feasibility of developing a large-scale, long-term project that could involve a much expanded number of participants with a greater diversity of backgrounds than have ever been tested before. The studies reported here were conducted with the goal of assessing the feasibility of undertaking such a project to investigate the cognitive development of an existing population of chimpanzees—those who are currently being, or have been, reared in human homes with human “foster parents.” Based on our own preliminary surveys, we estimate that more than 150 such animals currently exist in the United States alone and, of these chimpanzees, upwards of 75 are currently residing in human households. The existence of this very special population permits comparative psychologists to envision the possibility of designing an extensive, longitudinal research program that would investigate and track the development of cogni-
tive abilities in a large number of individual chimpanzees. These studies show that they could in principle be recruited. Also, survey instruments could be carefully developed to provide a detailed assessment of their rearing environments, their participation in a large-scale project would be invaluable. One of the benefits of any such project is that chimpanzees with various rearing histories could travel to a single test facility, allowing for direct comparison with the performances of chimpanzees from other rearing backgrounds tested in a comparable environment using highly standardized experimental procedures. In addition, testing of the chimpanzees could be carefully coordinated to provide a longitudinal assessment of the development of their cognitive abilities. Although, the task of implementing such a large-scale and long-term project is obvious, the three chimpanzees who participated in these initial studies encourage us by providing practical demonstrations of the project’s feasibility. These chimpanzees adapted rapidly to the novel environment, objects, and tasks, evidencing that they could be tested on multiple, diverse, experimental tasks within the time frame of approximately one week.

If conducted properly, this project could make an invaluable contribution to the understanding of the plasticity of psychological development in both our own species and other closely related species. The types of tasks presented to the participants in this project should not be limited to those investigating their social and physical reasoning abilities, but should tap into the broadest range of domains, drawing on the expertise of a range of scholars. The results of such an extensive series of studies are unlikely to provide a uniform answer to the question of whether the cognitive capacities of another species can be molded by the human rearing experience in such a way as to fundamentally re-sculpt their cognitive architecture (in the vein of social constructivist theory), or whether fundamental changes occur only in very specific components of the cognitive system, or whether the cognitive capacities of these specially enriched chimpanzees might undergo no substantial changes at all (regardless of whether they develop an atypical skill set relative to their peers raised outside of human culture). Even glimpses of answers to such historically profound questions concerning the plasticity of development can provide insight into the identification of unique aspects of human cognition, and the degree to which such unique traits are constrained by our biological endowment, and our unique cultural practices.

References


**Appendix**

**Chimpanzee Rearing Environments**

All three participants came from private breeders and were kept with their natural mothers until about a week before they were received by their human families (at the approximate age of 6 weeks). From this point on, they were considered members of the human family. Until roughly one-year of age, they were hand-bottle-fed, slept in cribs in the caregiver’s room, and remained in the main house and outdoor yard. The chimpanzees were engaged with toys and activities that are typical of human children; for example, stuffed animals, balls, plastic interactive toys, blocks, pull-toys, mechanical toys, colors, paints, blankets, peek-a-boo-type games, books, televisions etc. At around 3-years-old, the chimpanzees began spending more time in their outdoor enclosures during the day. At night, one of the participants (03-002) maintained sleeping in the main house, while the other two resided mainly in enclosures detached from the main house. All participants wore diapers daily, and clothing frequently, ate with feeding utensils in high chairs, rode in cars and strollers, ate out in restaurants, and interacted with human children occasionally, and human adults daily. Of the three participants, two had other chimpanzees living with them from infancy, and one (03-004) was about the age of three when integrated with another chimpanzee. All animals were bathed weekly until about 4-years-old. All families had dogs and cats as part of the household.

All participants were recruited to the project through in-person interviews between the chimpanzee caregivers and the research staff. Caregivers were contacted through personal contacts and recommendations and their participation in this project was entirely voluntary.