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A Longitudinal Investigation of Chimpanzees' Understanding of Visual Perception

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Seven chimpanzees were tested for their understanding of the intentional aspect of visual perception at 5–6 years of age and again at 7 years of age. They appeared not to understand that they should use a species-typical, visually based begging gesture in front of someone who could see them, as opposed to someone who could not. Four experiments that were conducted when these same subjects were adolescents are reported here. The results suggest that there was no development between 5 and 9 years of age in the animals' understanding of visual perception as an internal state of attention. The subjects appeared to learn procedural, stimulus-based rules related to the frontal orientation, the face, and the eyes of the experimenters. Even subjects most adept at these tasks appeared to rely on stimulus-based rule structures, not an attribution of "seeing."

INTRODUCTION

In an extensive series of experiments, Flavell and his colleagues have characterized at least two levels of young children's understanding of seeing as a mentalistic act (Flavell, Everett, Croft, & Flavell, 1981; Flavell, Flavell, Green, & Wilcox, 1980; Flavell, Shipstead, & Croft, 1978; Lempers, Flavell, & Flavell, 1977; Masangkay, 1974). At the simplest level, their research has demonstrated that 2-year-old children can answer questions about what another person can or cannot see, and furthermore can produce the set of conditions necessary to prevent or allow an object to be seen by someone (e.g., nonegocentrically hiding an object behind a screen). In contrast to their understanding of this attentional aspect of seeing, Flavell and colleagues have repeatedly shown that 2- and even 3-year-old children do not appear to understand that the experience of seeing leads to an internal, specific point of view on the world. This second level of understanding seeing appears to emerge at around 4 years of age. By this point, children appear to understand that when a person looks at something, they see it from a certain perspective, and hence an object or event appears in a certain way to the observer. Thus, when a 4-year-old sees someone looking at an upside-down picture, he or she knows that it appears upside-down to that person, despite the fact that he or she sees it right-side up. In folk psychological terms, 4-year-olds may be thought of as understanding that seeing leads to an internal, mental perspective. As mentioned earlier, younger children fail to grasp this fact.

Consistent with these findings, more recent research has shown that although children 4 years and older understand that someone who sees an object or event possesses privileged knowledge relative to someone who has not, younger children seem largely oblivious to this fact (Povinelli & deBlois, 1992; Ruffman & Olson, 1989; Wimmer, Hogrefe, & Perner, 1988; for possible competence in younger children see Pillow, 1989; Pratt & Bryant, 1990). The same developmental effect appears to be present with respect to children's ability to understand how they themselves came to know a fact—younger than about 4 years of age, children seem largely unaware of the causal role that visual perception (or other modes of perception) plays in determining the particular knowledge states that they hold (Gopnik & Graf, 1988; Mossler, Marvin, & Greenberg, 1976; O'Neill, Astington, & Flavell, 1993; O'Neill & Gopnik, 1991; Povinelli & deBlois, 1992; Wimmer et al., 1988). Thus, like Flavell's results, these findings suggest that before about 4 years of age, children do not interpret seeing (or perception in general) as having internal, mental consequences for the perceiver. Nonetheless, recent experimental evidence has also confirmed the findings of Flavell's group by showing that despite their inability to appreciate the perception-knowledge relation, 2½-year-old children at least understand that a person's visual orientation intentionally connects them to events or objects out in the world (Gopnik, Meltzoff, & Esterly, 1995; O'Neill, 1996; Povinelli & Eddy, 1996a, Experiment 15). Studies of even younger infants' abilities to track the gaze of others, as well as their ability to use a speaker's orientation and verbal or emotional outbursts to determine the object of his or her reference, have been used to bolster the idea that prior to understanding seeing per se, infants understand something about attentional focus. However, the exact nature of this understanding is widely debated (Baldwin, 1991, 1993a, 1993b; Baldwin & Moses, 1994; Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Corkum & Moore, 1994; Scaife & Bruner, 1975).

Povinelli and Eddy (1996a) compared young children and chimpanzees' understanding of seeing to determine whether chimpanzees understand that a person's face and eye direction signifies the deployment of attention. In other words, they sought to determine if chimpanzees at least understand seeing in the manner expressed by 2- to 3-year-old human children. In a series of 14 experiments, spanning 6 months, seven experimentally sophisticated 5- to 6-year-old chimpanzees were administered a number of tests to determine if, in the context of requesting food, they would selectively gesture to someone who could see them as opposed to someone who could not. The subjects were initially trained to enter a plexiglas test unit, look to see whether a familiar experimenter was seated on the right or left, and then use a species-typical begging gesture to request a food reward by reaching through a hole directly in front of the experimenter. The subjects were then confronted with probe trials, in which two experimenters were present (one on the right and the other on the left). One of these experimenters could see the subject, the other could not. For example, several of the treatments involved one of the experimenters using an object such as a bucket or screen to obstruct his or her entire face, whereas another experimenter held an identical object in such a way that did not obstruct his or her vision. Other treatments did not involve objects, but rather the posture or the behavior of the two experimenters resulted in one being able to see and the other not. For example, one experimenter had his or her eyes open and the other had his or her eyes closed, or one experimenter faced forward and the other had his or her back to the subject. When the subjects gestured to the experimenter who could see them, this person handed them a food reward; if they gestured to the experimenter who could not see them, no food reward was offered.

Remarkably, the results of these tests suggested that the chimpanzees were not interpreting these situations as instances of seeing versus not seeing. As can be seen in Table 1, on every treatment except back/front, the subjects initially deployed their begging gestures randomly between the two experimenters, making no distinction between the person who could see them and the person who could not. The only treatment in which the subjects responded correctly from Trial 1 forward was the back-versus-front treatment. However, careful follow-up tests revealed that even in this treatment the subjects' success was probably the result of factors unrelated to the subjects' understanding of seeing (see Povinelli & Eddy, 1996a, Experiment 3). During the course of the 14 experiments, the subjects did learn a number of rules that allowed them to perform successfully on most of the treatments. Initially, the subjects appeared to extract a "face rule," which could be verbally described as, "gesture to the person whose face is visible." Using this face rule, the subjects were able to solve the treatments in which one experimenter's entire face was visible, and the other's was absent (e.g., buckets, screens, hands-over-eyes), but not those in which an equal amount of the face was obstructed (e.g., blindfolds over the eyes versus blindfolds over the mouth). After additional experience, however, the subjects also appeared to extract an "eyes rule" that allowed them to solve these problems as well (i.e., "gesture to the person whose eyes are visible"). Even this latter rule appeared to be largely stimulus based, as the subjects still failed to grasp the distinction between

Table 1 Summary of Group Performance by Treatment at First Longitudinal Time-Point (Age 5–6 Years)

	Percent Correct in Blocks of Four Trials												
Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13
Attending/distracted	53.6	75.0*	–	–	–	–	–	–	–	–	–	–	–
Back/front[a]	91.7	91.7	83.3	87.5	95.8	91.7	95.8	100	100	100	100	100	95.8
Blindfolds[a]	54.2	37.5	54.2	62.5	–	–	–	–	–	–	–	–	–
Buckets[a]	58.3	91.7*	–	–	–	–	–	–	–	–	–	–	–
Eyes open/closed	57.1	–	–	–	–	–	–	–	–	–	–	–	
Hands-over-eyes/ears[a]	50.0	66.7	41.7	70.8	–	–	–	–	–	–	–	–	–
Screens[a]	50.0	58.3	83.3	50.0	58.3	70.8	91.7*	–	–	–	–	–	–
Shoulders[a]	50.0	70.8	70.8	87.5	79.2	79.2	100	87.5	95.8**	–	–	–	–

[a] Means based on six animals only because the seventh subject (Candy) did not participate in all trials blocks.
* $p < .05$, ** $p < .01$, where significance values are derived from paired *t*-tests comparing performance in first trial block to performance in last trial block.

one experimenter who faced the chimpanzee with eyes open, and a second experimenter who also faced the subject, but whose face and eyes were oriented away from the subject as the experimenter distractedly stared into a corner of the room above and behind the subject. In contrast to the performance of the apes, 2½- and 3-year-old children who were tested on the same procedures displayed evidence of comprehending these conditions from Trial 1 forward (see Povinelli & Eddy, 1996a, Experiment 15).

One year after these initial tests, when the same chimpanzees were 6–7 years old, they were retested using several of these same treatments (see Povinelli, 1996a). Despite the fact that at the end of the initial set of studies the subjects were responding at levels far exceeding chance on the treatments that could be solved by applying the face rule, at this second time-point, the subjects uniformly responded randomly (see Table 2). For example, when they were administered the screens treatment, the subjects responded randomly for eight consecutive trials, and only gradually began to show moderate improvement. In addition, after 48 massed trials of the eyes treatment, the subjects were still responding at chance levels. Only the back-versus-front performance remained stable, and here the subjects responded at levels exceeding chance from Trial 1 forward (compare Tables 1 and 2). At the very least, these results suggested that regardless of the exact content of what the subjects had learned a year earlier, very little had been retained (see Povinelli, 1996a).

This report describes a series of four experiments that were conducted with the same seven chimpanzees used in the studies described above when they were full adolescents (between 8 and 9 years of age). The experiments were conducted as a third and final time-point in the longitudinal project described above. These studies were undertaken in an effort to test the hypothesis outlined by Povinelli and Eddy (1996a) that these chimpanzees may have failed the earlier tests due to their young age (for similar criticisms, see Povinelli, 1996a, 1996b; Tomasello, 1996). As they and others have noted, it is possible that chimpanzees and humans construct the same understanding of visual perception, but that in relative terms, human development occurs more rapidly. Thus, results with 5- to 6-year-old chimpanzees might be comparable to results with children younger than 2 years of age. Indeed, there is some evidence concerning rates of sensorimotor development that are at least consistent with this possibility (see Povinelli, 1996b; Povinelli & Eddy, 1996a). Thus, examining older chimpanzees on these tests is crucial to determining whether this species ever develops an intentional understanding of visual perception. To put it simply, apes grow up, too.

Given our subjects' extensive previous experience with this general task, any differences we obtained at this time-point might be attributable either to practice effects or to aspects of cognitive development relevant to a deeper understanding of seeing as attention. Thus, the current experiments were designed to maximize the likelihood of distinguishing between these two broad explanations. More specifically, the experiments were designed with several questions in mind. First, we wished to know if the subjects would display better evidence of retention of performance on our tasks than they had when they were juveniles. Second, we wished to determine if they would display a qualitative shift in their performance level, perhaps indicating the maturation of certain cognitive abilities not present at earlier time-points. Finally, we provided the subjects with extensive experience on a range of treatments, and then used a combination of novel treatments to determine the factors controlling their choices.

EXPERIMENT 1

In Experiment 1 we retested the subjects using treatments that instantiated two of the rule structures described earlier (face rule, eyes rule), as well as a treatment that could not be solved by either rule, and instead might require understanding something about attention as a mental state (or, eventually, learning a specific conditional discrimination). A number of outcomes were possible. First, the subjects might display little evidence of immediate success on the probe trials. This outcome would be most consistent with the view

Table 2 Summary of Group Performance by Treatment at Second Longitudinal Time-Point (Age 7–8 Years)

	Percent Correct in Blocks of Four Trials											
Treatment	1	2	3	4	5	6	7	8	9	10	11	12
Back/front	92.9	—	—	—	—	—	—	—	—	—	—	—
Eyes open/closed	50.0	35.7	35.7	50.0	50.0	53.6	67.9	39.3	32.1	53.6	67.9	32.1
Screens	46.4	60.7	60.7	53.6	60.7	53.6	—	—	—	—	—	—

that our subjects originally did not understand the mentalistic significance of seeing, nor had they developed such an understanding in the interim. Second, we might uncover mixed success, where the subjects performed well on some probe trial types, but not on others. This mixed success would be more difficult to interpret in a straightforward manner. A final possibility was that the subjects would display immediate, across-the-board success on the various treatments. Given their limited retention at the second timepoint in this project (Povinelli, 1996a), this step-like improvement would suggest that the subjects had developed an appreciation of the attentional significance of our tasks.

Method

Subjects

The subjects were seven adolescent chimpanzees (*Pan troglodytes*). Six of the subjects were female (Kara, Candy, Jadine, Brandy, Megan, Mindy) and one was male (Apollo). Their ages ranged from 7 years and 7 months (7,7) to 8,6 at the start of this study. The subjects were housed together in a large indoor-outdoor compound at the University of Southwestern Louisiana New Iberia Research Center. As described above, all of these subjects had participated in a number of experiments using protocols very similar to those employed here when they were 5 to 6 years old, and again briefly when they were 6 to 7 years old. In the interim, the subjects had been tested on a number of procedurally different tests to examine their understanding of attention, intention, pointing, and several other cognitive phenomena (Povinelli, Bierschwale, & Čech, in press; Povinelli & Eddy, 1996a, 1996b, 1996c, 1997; Povinelli, Perilloux, Reaux, & Bierschwale, 1998; Povinelli, Reaux, Bierschwale, Allain, & Simon, 1997; for details of the animals' early rearing and experimental histories and their living environment, see Povinelli & Eddy, 1996a).

General Setting

Testing typically took place twice daily. Individual subjects exited the social group and entered an outdoor waiting area. In the context of other experimental protocols, all of the subjects had extensive experience with this procedure. This waiting area was connected to an indoor test room by a remotely operated shuttle door that allowed the subjects to enter and exit as required. The test room was divided by a plexiglas partition so that work spaces were available for both the experimenters and the subjects. The plexiglas partition contained several holes (14 cm in diameter) through which the subjects could easily reach. Two holes, separated by a distance of 80 cm (hereafter, the left and right holes), were used for the subjects' responses. Food rewards consisted of vanilla wafer cookies, fresh fruit, and candy. (The subjects' primary caretaker served as trainer, and this was the same person involved in the Povinelli and Eddy, 1996a, studies. The experimenters to whom the chimpanzees responded were different from those used previously, although the chimpanzees were used to interacting with them on a daily basis.)

Procedure

Pretest. In order to reacquaint the subjects with entering the test unit and gesturing through an appropriate hole toward an experimenter, all subjects initially received pretest sessions, each containing six baseline trials. These baseline trials involved one experimenter seated 100 cm from the plexiglas, positioned in front of one of the two holes. The gaze of the experimenter was fixed 15 cm above the hole in front of them. The subject's task was to enter, gesture through the correct hole toward the experimenter, wait for the experimenter to hand them a reward, and then exit the test room. Throughout this phase and for all subsequent trials and experiments, a choice was defined as the first hole through which the subject's hand passed. The side on which the experimenter was positioned was randomized within the constraint that he or she appear equally often on both sides. All subjects met the criterion of five or more correct trials out of six for two consecutive sessions, and were advanced to the testing phase.

Testing Procedures. Each test session consisted of six trials. Four of these were baseline trials (identical to those in the pretest phase) and two were probe trials. The position of the probe trials within the sessions was determined randomly within the constraints that (1) the probe trials were never administered on Trial 1, and (2) no probe trials occurred consecutively. The probe trials were used to administer the experimental treatments described below. On probe trials two experimenters were present, one in front of the right hole, the other in front of the left hole. Each subject received four trials of every treatment (6 treatments $\times$ 4 trials = 24 total probe trials; 2 probe trials per session = 12 total sessions). The order in which the subjects received the trials of the various treatments was determined by randomly and exhaustively assigning them in groups of six, so that each subject received one probe trial of each treatment type before receiving a second, and so on. The side (left or right) on which each treatment was correct was equated across sessions.

Treatments used in testing. Six of the experimental treatments administered to these subjects by Povinelli and Eddy (1996a) were used. Visual depictions of each treatment can be found in Figure 1. In the screens treatment, both experimenters were holding opaque screens, but one used it to cover his or her face, whereas the other held it above his or her shoulder. Similarly, in the buckets treatment, one experimenter held a bucket so that it fully covered his or her head, whereas the second experimenter held a bucket in the same manner over his or her shoulder. In the blindfolds treatment, one experimenter's eyes were cov-

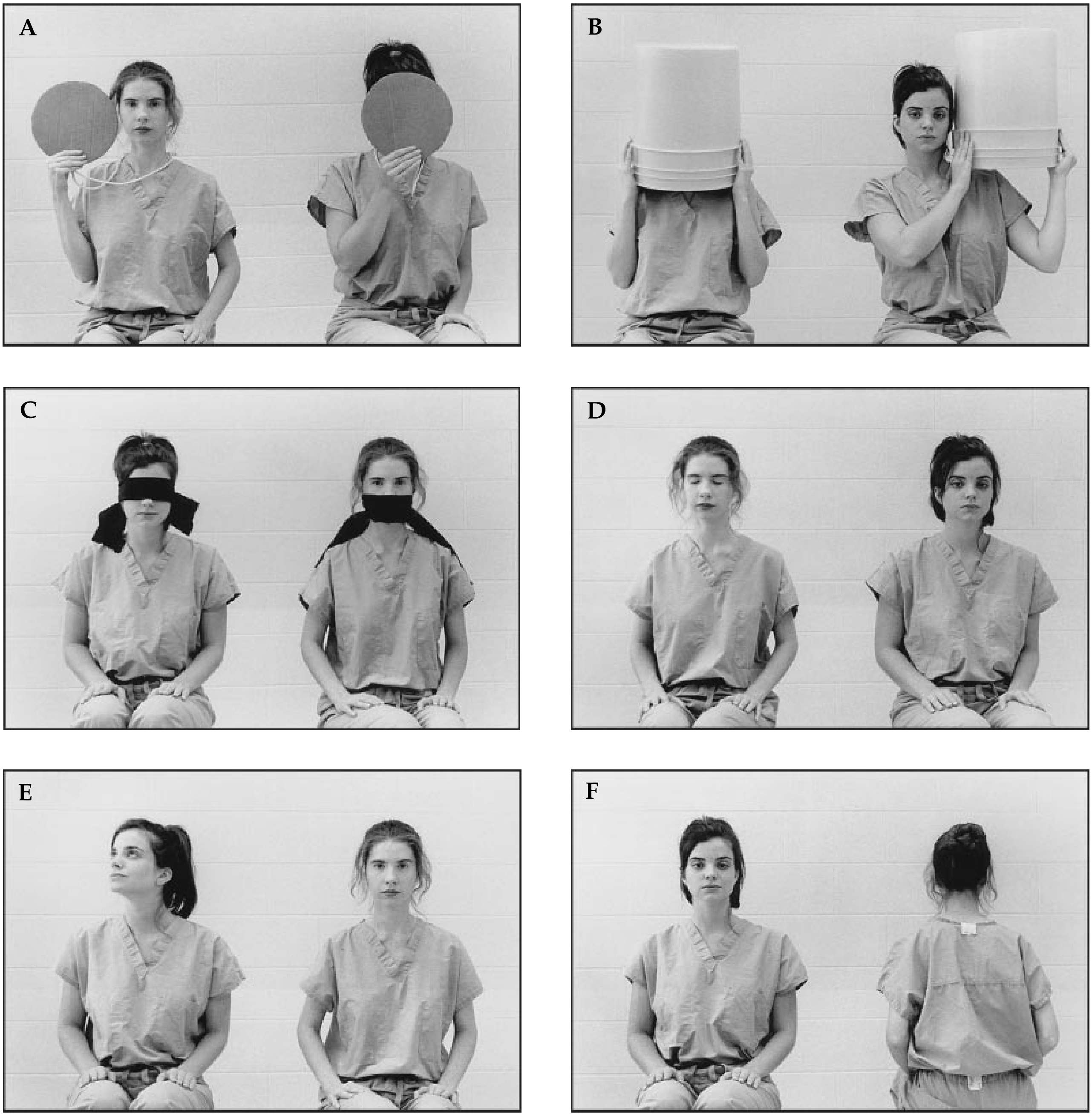

Figure 1 Stimulus configurations for treatments used in experiments 1 and 2: (A) screens, (B) buckets, (C) blindfolds, (D) eyes, (E) attending-versus-distracted, (F) back-versus-front. The left/right position of the correct choice and individual experimenters, along with the identity of the experimenter associated with the correct choice, were randomized within the counterbalancing constraints described in the text.

ered with a blindfold, whereas the other's mouth was covered. In the eyes treatment, one of the experimenters had his or her eyes open, whereas the other's eyes were closed. In the attending-versus-distracted treatment, one experimenter was visually attending, whereas the other was looking away at a predetermined location above and behind the subject. Finally, in the back-versus-front treatment, one experimenter was seated forward facing the subject, whereas the other was seated with his or her back to the subject. In all treatments, the correct experimenter gazed 15 cm above the appropriate hole until the subject made a response. When the subjects gestured through the correct hole, the experimenter made eye contact with them, offered verbal praise, and then handed them a food reward. If the subject gestured through the incorrect hole, no reward was offered and the trainer ushered the subject out of the test unit.

Data Analysis

The number of trials in which each subject was correct (out of four) was used to calculate the percent correct for each subject for each treatment type. The subjects' scores within each treatment were then averaged to produce an overall percent correct for each treatment. Separate one-sample *t* tests (two-tailed, hypothetical $M = 50\%$) were used to determine whether the subjects responded at levels exceeding chance within each of the six treatments. A one-way repeated-measures analysis of variance (ANOVA) was used to determine if the subjects' responses differed as a function of treatment.

Results and Discussion

The subjects performed at ceiling levels (99% correct) on the baseline trials (only one experimenter present) that surrounded the probe trials, demonstrating that they were generally attending and highly motivated to respond to the task. These background trials are therefore not considered further.

The left hand panels of Figure 2 depict the subjects' performance across the treatments in blocks of two trials. The most striking result is the discrepancy between the subjects' flawless performance on the back-versus-front probe treatment as compared to their performances on the other treatments. Indeed, a one-way repeated measures ANOVA indicated an overall effect of treatment, $F(3, 30) = 5.87$, $p < .001$, and post hoc Tukey Kramer Multiple Comparison Tests revealed that the subjects performed significantly better on the back-versus-front treatment than all other treatments, $p < .05$ or smaller, except the buckets treatment. No other treatments differed from each other. The second major finding is that the subjects tended to perform better on the treatments that could be solved by use of the face rule (buckets, screens) as compared to those that could be solved by the eyes rule. In fact, the only treatment (other than back-versus-front) in which the subjects performed at levels exceeding chance was buckets, a treatment in which the face rule could be applied, $t(6) = 3.24$, $p < .02$, although the subjects also tended to prefer the correct option in the screens treatment (65% correct). In contrast, in those treatments that required the subjects to use the eyes rule, performance did not exceed that expected by chance (blindfolds: 52% correct; eyes: 57% correct). Lastly, the subjects' performance did not exceed chance in the attending-versus-distracted treatment (58% correct). The data were next examined for evidence of learning effects. Separate paired *t* tests indicated that the subjects' performances on trials 1 and 2 did not differ from their performances on trials 3 and 4 for any of the treatments.

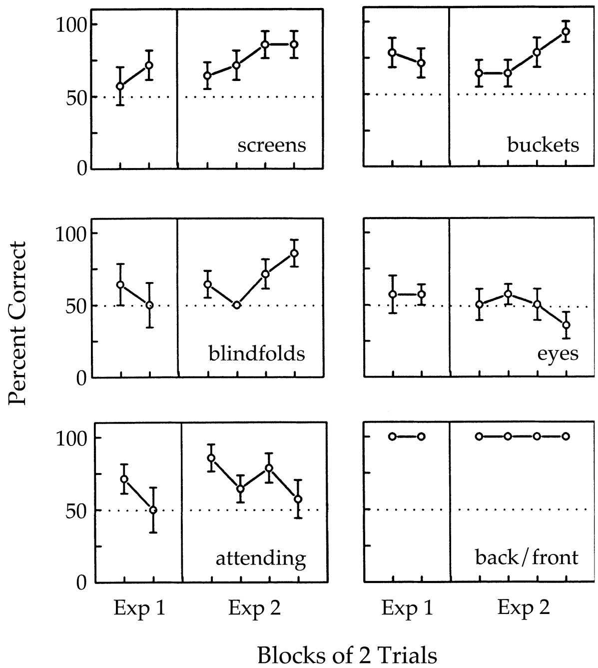

Figure 2 **Results of probe trials by treatment in experiments 1 and 2 presented in percent correct (±*SEM*) in blocks of two trials. Dotted line indicates performance expected by chance.**

In a more direct comparison of the subjects' understanding of the face rule versus the eyes rule, we collapsed each animal's performance in the screens and buckets treatments for a mean score the treatments that could be solved by use of the face rule, and the blindfolds and eyes open/closed treatment for a second mean score on treatments that could be solved by use of the eyes rule. First, separate one-sample *t* tests (two-tailed, hypothetical $M = 50\%$) indicated that the subjects' mean performance on the face rule treatments was significantly above chance, $t(6) = 2.98$, $p < .03$, but their performance on the eye rule treatments was not. However, a paired two-tailed *t* test indicated that their mean score in these two collapsed treatments did not differ from each other.

Finally, the data were examined for individual differences among the subjects' performances (see Table 3). If one adopts 75% or better as a criteria for successful performance, of particular interest is that two of the subjects (Brandy, Candy) scored 75% or better on all treatments except attending-versus-distracted. In addition, Megan scored perfectly on the face rule treatments, but responded at chance on all other treatments (except, of course, back-versus-front). Curiously, Apollo performed perfectly on the buckets and attending-versus-distracted treatments, but performed at chance levels on the other treatments. The remaining animals (Kara, Jadine, Mindy) scored perfectly on back-versus-front, but performed at chance levels on the other treatments.

In general, these results seem most consistent with the idea that the subjects approached the task in a similar manner as they had at both earlier time-points in this longitudinal project. Although as a group they performed well on one of the treatments that could be solved by applying the face rule (buckets), they did not exceed chance on the other treatment which could be solved by applying the same rule (screens). Also as a group, the subjects responded at chance levels on both treatments requiring use of an eyes rule, as well as the one that might require understanding the direction of an experimenter's attention. Even the two subjects (Candy, Brandy) who performed well on the treatments that could be solved by the eyes rule did not exceed chance performance on the attending-versus-distracted treatment. However, the otherwise excellent performance of these two subjects leaves open the possibility that they may have developed an understanding of the attentional processes underwriting seeing.

EXPERIMENT 2

Before conducting more direct tests of the idea that some of the subjects had developed a deeper understanding of seeing than was evident in the original series of studies (i.e., Povinelli & Eddy, 1996a), we conducted an extended replication of Experiment 1 in order to assess the reliability of the findings for certain subjects, as well as to track possible learning effects in the other subjects.

Method

The same seven chimpanzees used in Experiment 1 participated in this study. At the time this experiment began, the subjects were 3 months older (age *range* = 7,10 to 8,9).

Except as noted, the general testing procedures and experimental treatments were identical to Experiment 1. As before, the subjects were given an initial orientation session consisting of six baseline trials in order to reacquaint them with entering the test unit, requesting a food reward from an experimenter, and exiting. Criterion to advance to testing was set at 5 or more correct responses within a session. All subjects met this criterion in the first session.

Testing again consisted of baseline trials interspersed with probe trials. Two minor changes were introduced for testing. First, to prevent the subjects from slapping at the experimenters as they waited for

Table 3 Subject-by-Subject Summary of Correct Choices in Experiment 1

	Treatments					
Subject	Screens	Buckets	Blindfolds	Eyes Open/ Closed	Attending/ Distracted	Back/Front
Kara	2/4	2/4	2/4	1/4	2/4	4/4
Candy	3/4	3/4	3/4	3/4	2/4	4/4
Jadine	2/4	3/4	1/4	2/4	3/4	4/4
Brandy	3/4	3/4	4/4	4/4	1/4	4/4
Megan	4/4	4/4	2/4	2/4	2/4	4/4
Mindy	2/4	2/4	2/4	2/4	2/4	4/4
Apollo	2/4	4/4	2/4	2/4	4/4	4/4
M =	2.6	3.0*	2.1	2.3	2.3	4.0[a]

[a] No statistical test conducted because group variance = 0.
* $p < .05$.

a food reward, the distance of the experimenters from the plexiglas was increased from 100 to 120 cm. Second, each subject received each experimental treatment eight times (6 treatments × 8 trials = 48 total probe trials; 3 probe trials per session = 16 sessions). Third, the number of trials within each test session was increased to seven (so that three probe trials could be administered within each session instead of two). The order in which the treatments were assigned was determined by randomly and exhaustively assigning to each subject separately one of each treatment type, and then repeating this procedure until all 48 trials were scheduled. The side (left or right) on which each treatment was correct was equated across sessions.

Results and Discussion

The right-hand panel of Figure 2 depicts the subjects' performance by treatment type in blocks of two trials. As in Experiment 1, the animals performed flawlessly on the back-versus-front treatment. They also scored significantly above chance on both of the treatments that could be solved by use of the face rule, screens: $M = 77\%$ correct, $t(6) = 4.66$, $p < .01$; buckets: $M = 75\%$ correct, $t(6) = 4.00$, $p < .01$. With respect to the treatments that could be solved by the eyes rule, the subjects performed above chance on blindfolds, $t(6) = 2.97$, $p < .05$, but not on the eyes treatment, $p = .76$. Finally, the animals performed significantly above chance in the attending-versus-distracted treatment, $M = 71\%$ correct, $t(6) = 4.00$, $p < .01$.

As in Experiment 1, we collapsed each animals' performance in the screens and buckets treatments for a mean score for treatments that could be solved by use of the face rule, and the blindfolds and eyes open/closed treatment for a second mean score for treatments that could be solved by use of the eyes rule. As in Experiment 1, separate one-sample t tests (two-tailed, hypothetical mean = 50%) indicated that the subjects' mean performance on the face rule treatments was significantly above chance, $t(6) = 4.83$, $p < .003$, but their performance on the eye rule treatments was not. Second, consistent with the idea the subjects were learning a face rule, a paired t test (two-tailed) indicated that their mean score in these two collapsed treatments differed from each other, $t(6) = 3.34$, $p < .02$, with the subjects performing better in the face rule treatments ($M = 75.9\%$ correct) than in the eyes rule treatments ($M = 58.0\%$ correct).

We next examined the data for evidence of learning across the course of this experiment. As can be seen in Figure 2, the patterns for the screens, buckets, and blindfolds treatments all indicate that the performance of the subjects improved with the repeated trials they received. In contrast, although the overall group mean was significantly higher than that expected by chance (see above), the performance of the subjects in the attending-versus-distracted treatment did not appear to improve across trials. In addition, no evidence of learning was detected for the eyes treatment. Here, performances remained flat and at chance levels across the eight trials they received.

Table 4 provides a summary of the performance of each subject by treatment. Several individual differences are of particular interest. Perhaps most striking is that the two subjects (Brandy, Candy) who performed well in Experiment 1 displayed worse performance in Experiment 2. For example, Candy's performances on the face and eyes treatments were at chance levels. Likewise, Brandy, who had performed perfectly (4/4 correct) on the eyes treatment in Experiment 1, performed at chance levels in response to the

Table 4 Subject-by-Subject Summary of Correct Choices in Experiment 2

	Treatments					
Subject	Screens	Buckets	Blindfolds	Eyes Open/ Closed	Attending/ Distracted	Back/Front
Kara	5/8	6/8	5/8	3/8	6/8	8/8
Candy	5/8	4/8	4/8	4/8	6/8	8/8
Jadine	7/8	7/8	4/8	4/8	5/8	8/8
Brandy	6/8	6/8	7/8	4/8	5/8	8/8
Megan	7/8	8/8	7/8	6/8	8/8	8/8
Mindy	8/8	6/8	6/8	2/8	5/8	8/8
Apollo	5/8	5/8	5/8	4/8	5/8	8/8
M =	6.1**	6.0**	5.4*	3.9	5.7**	8.0[a]

[a] No statistical test conducted because group variance = 0.
* $p < .05$; ** $p < .01$.

same treatment in this experiment (4/8 correct). On the other hand, one of the other subjects, Megan, gestured preferentially to the correct experimenter across all treatment types, including attending-versus-distracted (see Table 4), whereas in Experiment 1 she had scored well only on the treatments that could be solved by using the face rule (see Table 3).

The combined results of experiments 1 and 2 that are presented in Figure 2 reveal that in general the subjects learned several things during the first two experiments. First, their improved performance on the screens treatment (in combination with their earlier and continued success on buckets) suggests that the subjects learned a face rule to solve these treatments. However, their mixed success on the treatments that could be solved by using an eyes rule (blindfolds, eyes), suggests that in addition to the face rule, the subjects may also have learned highly specific rules corresponding to each treatment. Thus, as opposed to using a general theory about who could see them, or a series of hierarchically structured rules based on the face or eyes, the data leave open the possibility that the subjects were learning the correct option within each treatment type (i.e., "gesture to the person who has the blindfolds over the mouth"). An exception to this characterization may be Megan, whose excellent overall performance leaves open the possibility that she may have either learned something about attention as a general concept, or learned to apply some preexisting notion of attention in this context. (It should be noted, however, that even Megan displayed clear learning curves for the eyes, blindfolds, and the attending-versus-distracted treatments during the course of the two experiments.)

EXPERIMENT 3

In the next experiment we attempted to clarify the basis of the subjects' choices on those treatments in which they were now performing well. We sought to distinguish between whether this learning was limited to the stimulus characteristics of the experimenters' postures, or whether this learning also included an appreciation of the attentional significance of those postures. As an initial attempt to distinguish between these characterizations, we juxtaposed correct and incorrect options from a number of the treatments in order to form several mixed treatments. We reasoned that if the subjects had learned treatment-specific relational rules, their performance should drop substantially if a correct option from one treatment was mixed with an incorrect option from another. On the other hand, if the subjects had extracted a context-independent understanding that certain experimenter configurations were correct (i.e., associated with a food reward), whereas others were incorrect, they should perform well on such mixed treatments. Finally, we created an additional treatment by combining the correct option from a treatment they understood (blindfolds), with an incorrect option from a treatment they did not understand (eyes). The significance of this final mixed treatment was that if the subjects performed at chance levels it would suggest that they did not appreciate the mentalistic significance of the option from the blindfolds treatment, even though in the context of the original blindfolds treatment, they knew it to be "correct" (in the sense that it was associated with a reward from the experimenter).

Method

Subjects and Procedure

Experiment 3 began 3 days after the completion of Experiment 2, at which point the seven chimpanzees ranged in age from 7,11 to 8,10. The general procedure was similar to that of experiments 1 and 2. As in the earlier studies, before beginning the test sessions, all subjects were administered a pretest of six baseline trials. All of the subjects met a criterion of 5/6 correct or better and were therefore immediately advanced to testing.

Nature of Treatments

Five of the experimental treatments from the first two experiments were mixed to form three novel treatments (see Figure 3). In the +screens/−buckets treatment, the correct stimulus from the screens treatment was paired with the incorrect stimulus from the buckets treatment. Similarly, in the +screens/−distracted treatment, the correct experimenter held a screen over his or her shoulder, whereas the incorrect experimenter looked at a fixed target above and behind the subject. Finally, in the +blindfolds/−eyes treatment, the correct experimenter's mouth was covered by a blindfold, whereas the incorrect experimenter sat with eyes closed. Testing consisted of six sessions, each containing two probe trials and four baseline trials. Each treatment was administered randomly four times within the same constraints used in the previous experiments.

Results and Discussion

The left-hand panel of Table 5 depicts the results by subject. As a group, the subjects scored above chance in both the +screens/−buckets treatment, $t(6) = 5.28$, $p < .01$, and the +screens/−distracted treatment, $t(6) =$

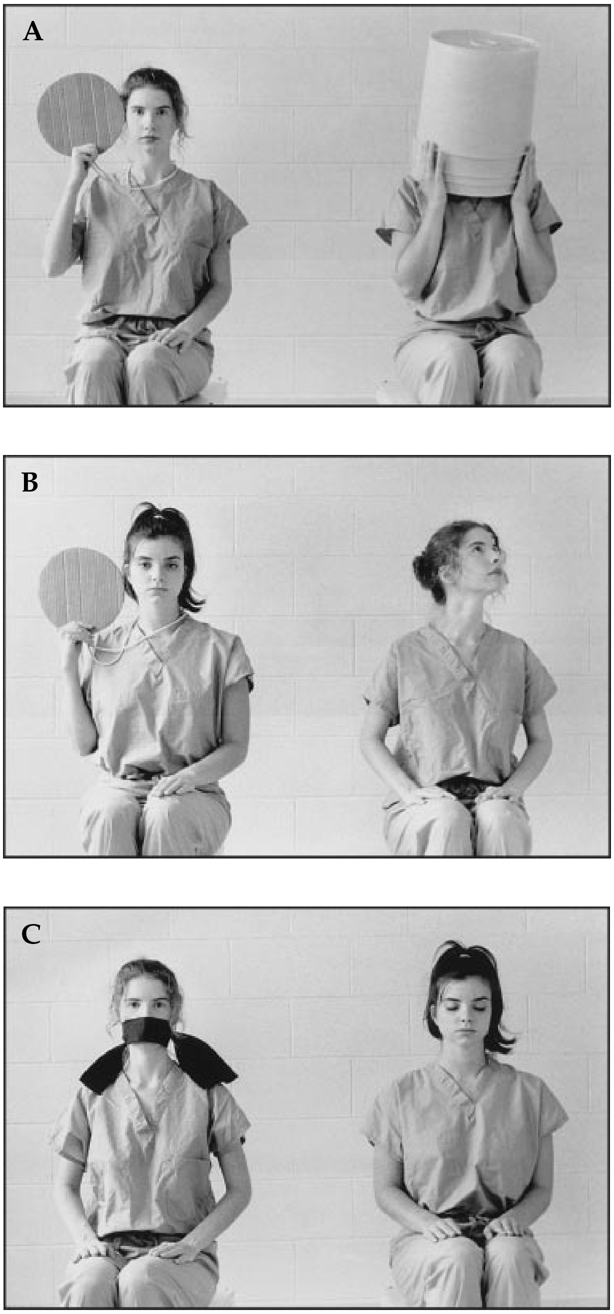

Figure 3 Stimulus configurations for treatments used in Experiment 3: (A) +screens/−buckets, (B) +screens/−distracted, (C) +blindfolds/−eyes. The left/right position of the correct choice and individual experimenters, along with the identity of the experimenter associated with the correct choice, were randomized within the counterbalancing constraints described in the text.

2.52, $p < .05$. In direct contrast, however, in the +blindfolds/−eyes treatment the subjects' responses did not differ from that expected by chance. A one-way repeated measures ANOVA indicated a significant overall effect, $F(2, 12) = 7.517$, $p < .01$, and Tukey-Kramer posttests revealed that this difference was due to the subjects' better performance on the +screens/−buckets treatment as compared to the +blindfolds/−eyes treatment, $p < .01$.

An examination of the data for individual subjects suggests that the animals were fairly uniform in their reaction to the +screens/−buckets treatment, as all but two subjects gestured to the experimenter whose face was visible (the +screens option) on every trial. The subjects responded more variably to the +screens/−distracted treatment, but the subjects' scores in this treatment were significantly correlated with their performance on the attending-versus-distracted treatment from experiments 1 and 2 (Pearson's correlation yielded a coefficient of determination, r^2 of .74, $p < .013$). This is to be expected, given that the overall configuration of the +screens/−distracted treatment differed from the original attending-versus-distracted treatment only in that one of the correct experimenter's arms was holding up a screen. Finally, with the exception of Candy and Megan, the subjects responded fairly uniformly in the +blindfolds/−eyes treatment by displaying no preference for either of the two options. Interestingly, however, Candy gestured selectively to the incorrect experimenter (the experimenter with his or her eyes closed) on every trial, suggesting that the face rule was controlling her responses. Megan, in contrast, displayed the most flexible set of responses by choosing the +blindfolds option on 3/4 trials in this treatment (indeed, her error in this treatment was the only error she made in this experiment).

Based on the subjects' random responses to the +blindfolds/−eyes treatment, a logically similar, but novel treatment was subsequently devised and implemented to cross-validate this finding. In this new treatment, the −eyes option was paired with the +buckets option. In this test (Experiment 3a), conducted 10 days after the completion of Experiment 3, the same general experimental procedures that were used previously were again implemented. Each subject received four sessions consisting of four baseline trials and one probe trial of the treatment described above. Results of this test can be seen in the far right hand column of Table 5. As a group, the subjects gestured randomly between the two options, precisely as they had done the +blindfolds/−eyes treatment in Experiment 3. With respect to individual subjects, Megan continued to perform well (3/4 correct), suggesting that her earlier performance on the +blindfolds/−eyes treatment (3/4 correct) was reliable. On the other hand, three of the subjects tended to prefer the −eyes option (Candy, Mindy, Apollo), indicating the dominance of a face rule.

Table 5 Subject-by-Subject Summary of Correct Choices in Experiments 3 and 3a

	Experiment 3			Experiment 3a
Subject	+screens/ −buckets	+screens/ −distracted	+blindfolds/ −eyes	+buckets/ −eyes
Kara	4/4	3/4	2/4	2/4
Candy	4/4	3/4	0/4	1/4
Jadine	4/4	2/4	2/4	2/4
Brandy	4/4	2/4	2/4	3/4
Megan	4/4	4/4	3/4	3/4
Mindy	2/4	2/4	2/4	1/4
Apollo	3/4	4/4	2/4	0/4
M =	3.6**	2.9*	1.9	1.7

* $p < .05$; ** $p < .01$.

EXPERIMENT 4

The overall pattern of results from the previous experiments suggested that the subjects were learning to use the face rule, and that this rule could be flexibly deployed in the context of the mixed treatments used in Experiment 3. Furthermore, one (Megan) and perhaps two (Brandy) of the subjects were beginning to learn how to solve the eyes treatment. One hypothesis concerning the nature of these subjects' decision-making process was that they had learned a series of procedural rules that could be arranged in a linear order of priority. Based on the results reported here, as well as those reported by Povinelli and Eddy (1996a), we constructed the following low-level model of this decision-making process. To begin, the animals scan for the frontal stimulus of an experimenter. If only one front is visible (as in the back-versus-front treatment) the subjects use this as the basis for determining to whom they will gesture. If both experimenters' fronts are visible, they next scan for the presence of a face. Again, if only one face is visible (as in the screens and buckets treatments), they use this as the basis for their choice. Finally, if both faces are visible (as in the eyes treatment), the model specifies that they will resort to the presence of the eyes. In treatments where none of these rules can be satisfied (e.g., attending-versus-distracted), the model predicts that the subjects should gradually learn conditional discriminations specific to the treatments themselves. The important (and novel) prediction of this simple model was that if the presence of the face and eyes was pitted against the presence of the frontal stimulus and face *without* the eyes (see Figure 4a), the subjects would choose the latter—even those subjects such as Megan, who on the surface at least, appeared to understand the eyes treatment. This low-level procedural model was contrasted with a high-level model which assumes that for each treatment on which the subjects respond correctly, they have some understanding of the attentional significance

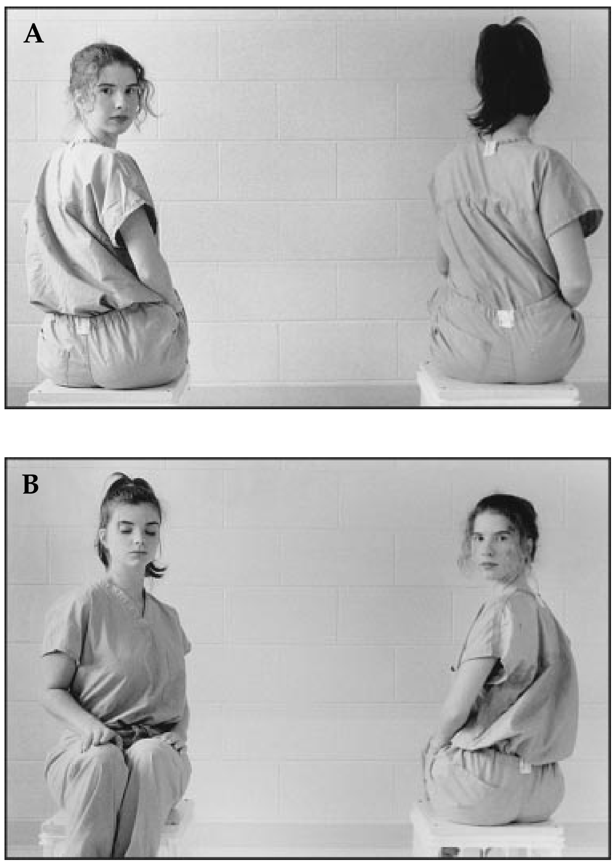

Figure 4 Stimulus configurations for new treatments used in Experiment 4: (A) looking-over-shoulder, (B) +eyes/−front. The left/right position of the correct choice and individual experimenters, along with the identity of the experimenter associated with the correct choice, were randomized within the counterbalancing constraints described in the text.

of the stimuli described above (e.g., frontal orientation, face, eyes). This high-level model posits that the subjects' learned performance reflects the fact that they represent the concept of attention as an internal psychological state and recruit it in order to make judgments concerning to whom they should gesture. Note that in direct contrast to the low-level model, this model predicts that in the mixed treatment just described the subjects should choose the experimenter with their eyes open (see also Predictions, below).

Method

Subjects and Procedure

The subjects began this experiment 15 days after completing Experiment 3a, at which point they ranged in age from 8,0 to 8,11. All subjects received one session of six baseline trials as an orientation. The criterion for advancement to testing remained at 5/6 correct responses, which all subjects met in the first session. Testing sessions consisted of eight sessions with six trials each. Two of these trials were probe trials and four were baseline trials. Each animals received four treatments (see below) four times each using the same counterbalancing constraints as in previous experiments.

Nature of Treatments

First, the following three treatments were administered as controls: back-versus-front, eyes, and looking-over-shoulder (a treatment that these subjects had previously received when they were 5 to 6 years old (at the first time-point in this longitudinal study; see Table 1). The looking-over-shoulder treatment involved both experimenters seated with their backs to the subject, but with one of the experimenters looking over his or her shoulder toward the subject (see Figure 4a). Second, a novel treatment, +eyes/−front, was constructed so that the correct experimenter sat backwards, looking over his or her shoulder at the hole directly in front of him or her, whereas the incorrect experimenter sat forward with torso at an angle matching the correct experimenter's position, and facing the hole directly in front, but with eyes closed (Figure 4b).

Predictions

The stimulus-based procedural model described above predicted that the subjects should perform above chance on both the back-versus-front and looking-over-shoulder treatments, but perform *below* chance on the novel +eyes/−front treatment. This latter prediction was most striking for subjects who performed above chance on the eyes treatment (especially Megan), because the high-level model predicted that such subjects should also perform above chance on this novel treatment.

Results and Discussion

The main results are summarized in Table 6. As in previous experiments, the subjects were flawless on the back-versus-front treatment. With respect to the three crucial treatments, the following results were obtained. First, in the looking-over-shoulder treatment, the subjects tended toward a significant preference for the correct option, the person looking over his or her shoulder, $t(6) = 2.29$, $p < .062$. Indeed, five of the seven subjects scored 75% or better on this treatment. Second, just as the stimulus-based procedural model predicted, and in direct contrast to the prediction of the high-level model, the subjects displayed a significant preference for the *incorrect* option (the experimenter facing forward with eyes closed) in the +eyes/−front treatment, $t(6) = 3.28$, $p < .02$.

Finally, although the subjects as a group did not display a significant or near-significant preference for the correct option in the eyes treatment, $p = .23$, two of the subjects (Brandy, Megan) were errorless on this treatment (4/4 correct), and another subject (Kara) scored 3/4 correct. Equally striking is that these same three subjects were 100% correct on the looking-over-shoulder treatment. However, despite the fact that these three subjects avoided the experimenter facing forward with eyes closed on the eyes treatment, and

Table 6 Subject-by-subject Summary of Correct Choices in Experiment 4

	Treatments			
Subject	Looking-Over-Shoulder	Eyes Open/Closed	+Eyes/−Front	Back/Front
Kara	4/4	3/4	1/4	4/4
Candy	2/4	2/4	2/4	4/4
Jadine	3/4	2/4	1/4	4/4
Brandy	4/4	4/4	1/4	4/4
Megan	4/4	4/4	0/4	4/4
Mindy	1/4	2/4	2/4	4/4
Apollo	3/4	1/4	1/4	4/4
M =	3.0*	2.6	1.1**	4/4[a]

[a] No statistical test conducted because group variance = 0.
* $p = .062$; ** $p < .05$.

that they selected the experimenter looking over his or her shoulder on the looking-over-shoulder treatment, when these options were combined in the +eyes/−front treatment (see Figure 4b), these subjects displayed a robust preference for the experimenter who could *not* see them—the one facing forward with eyes closed. Note that this is not a random performance, but rather a significant preference for the *incorrect* experimenter. As explained earlier, the procedural rule model predicted this counter-intuitive result because the general frontal stimulus (including a face) was present in the −front option from this treatment, but not in the +eyes option. However one chooses to interpret these results, they certainly do not easily lend themselves to an interpretation that even the subjects who had learned the most in these experiments understood anything at all about the relation of the face and eyes to an internal state of attention.

GENERAL DISCUSSION

The results of this longitudinal project provide fairly compelling evidence that our apes displayed no major cognitive reorganization with respect to their interpretation of visual perception between 5 and 9 years of age—at least in terms of the general task presented here. It is important to reiterate that the results of this longitudinal project cannot be dismissed as a lack of effects. First, at each time-point in this project the apes did display the ability to learn to discriminate between an experimenter who could see them and one who could not. Second, the subtlety of these discriminations were in some cases quite impressive, such as in the eyes treatment, in which some of our apes learned to select an experimenter with his or her eyes open as opposed to one with his or her eyes closed. Third, and perhaps most dramatically, in Experiment 4 of this report, the subjects actually displayed a significant preference for the experimenter who could *not* see them—a result predicted by the procedural rule model.

The results of this project cast a sobering light upon what our subjects learned as the result of the experiences in these tests. First, although within the trials administered at each time-point in this project our chimpanzees did learn the discriminations described above, this learning occurred only gradually (see, for example, Povinelli & Eddy, 1996a, Experiments 5–9; Povinelli, 1996a; and Experiments 1 and 2 reported in this article). Second, this learning did not emerge uniformly across treatments, as one might expect if these apes had learned to recruit a construct like "visual attention" to explain the contingencies we had established. Rather, the constructs they appeared to recruit were tightly stimulus bound such as "face," "eyes," and later, specific configurations of faces and eyes. Indeed, as Experiment 4 of this article clearly demonstrates, even those rules that might be thought of as being tightly associated with an understanding of visual attention (i.e., "gesture to the person whose eyes are visible"), were highly context-specific and of lower priority than other rules which had nothing to do with visual attention (see also Povinelli & Eddy, 1996a, Experiment 14). Finally, although we intentionally did not overtrain our animals at any of the time-points in this project, their weak retention of even the simplest of these rule structures (i.e., "gesture to the person whose face is visible") across these time-points reveals the fragile nature of their comprehension. This fact is even more impressive when one considers that during the lengthy intervals between the major time-points in this project, these animals were not idle. To the contrary, they participated in over two dozen other studies in which the central relevant construct was attention. Indeed, one reading of our results is that, far from serving to bootstrap our subjects' understanding of the central theme of our nonverbal inquiries, these other studies may have interfered with their retention of the rule structures relevant to these tasks.

On the other hand, one might wonder if some of our apes' experiences may have interfered with their later performance. An examination of the archival records for all trials administered to these subjects (prior to the studies reported here), reveal that each subject (except Candy, who began the project at a later time-point than the rest) received a total of 696 trials in which they were presented with a choice between two persons. In some of these cases the reinforcement was based on who could see them. In other cases both experimenters could see them, but one was offering a desirable reward and the other was offering an undesirable block of wood. In still other cases, both subjects could see the experimenters but one was making direct eye contact or moving their head. Finally, in some cases, neither experimenter could see the subjects. On 670 (96.3%) of these trials, the subjects were handed a reward (or the block of wood, in the cases where someone was offering it) when they gestured to a experimenter who could see them, and were not handed a reward if they gestured to an experimenter who could not see them. On the remaining 26 trials, several different contingencies applied, but on the majority of these trials ($n = 22$) the subjects were nondifferentially reinforced (e.g., if the subject gestured to a person whose eyes were closed, the trainer gave a signal that alerted the experimenter to open his or her eyes and hand the subject a reward). These trials were conducted to examine the relative importance of head orientation, motion, direct eye contact, and presence of visual attention of the subjects' responses (see Povinelli & Eddy, 1996c). Importantly, however, none of these latter trials occurred before the initial use of the eyes open/closed treatment during the first longitudinal time-point (see Table 1), or after the 48 blocked trials of eyes open/closed administered at the 6–7 year time-point (see Table 2). Finally, if we restrict our analysis to just those 378 trials where one experimenter could see the subjects, and the other experimenter could not, on 360 (95.2%) the subjects were reinforced only if they gestured to the experimenter who could see them.

One (we feel incorrect) conclusion that might be drawn from this longitudinal project is that our results reveal that eye presence, direction, and movement are not salient social stimuli for chimpanzees, who maybe attend solely to the head posture or general bodily orientation of others. There are several problems associated with such an interpretation. First, across the time-points of this project, our subjects showed little evidence of retaining their performances—even in those cases where they could rely on the presence of the face alone, without having to keep track of the eyes. Second, Povinelli and Eddy (1996b, Experiment 1) have demonstrated that these same chimpanzees follow gaze of experimenters in response to their eye movement alone (that is, with their head remaining motionless). Indeed, this effect is statistically indistinguishable from their gaze-following in response to head and eye movement in concert. Third, Povinelli and Eddy (1996c) have demonstrated that if other factors are held constant, these same chimpanzees tend to be more attracted to persons who make direct eye contact with them, as opposed to others who do not. Such formal experimental demonstrations of chimpanzees' sensitivity to eye movement and direction are consistent with the daily socioecology of chimpanzees. For example, during midday rests chimpanzees regularly lie or sit with their eyes alternately open or closed, as others approach them for social interactions such as grooming or bouts of play. Finally, even the most casual face-to-face interactions with chimpanzees reveal that eye movement occurs independent of head or body movement, and is easy to detect given the differential coloration of their iris/pupils relative to their sclera.

Despite the results reported in this article, it is important to be cautious about their wider implications. First, here and elsewhere we have distinguished between an organism's understanding of visual attention on the one hand, and attention in general on the other (see Povinelli & Eddy, 1996a, Chapter 6). For example, it is possible that chimpanzees do, in fact, possess a concept of attention much like that which emerges in human development, except that they do not afford the eyes (or even the face) special status in its deployment. Indeed, previous empirical results offer some hint that this may be the case, as we have shown that chimpanzees are more likely to gesture to an experimenter engaging in species-typical postures or head movements with their eyes closed, than to another experimenter merely looking at them (Povinelli & Eddy, 1996c, Experiment 3). In this particular case, eye contact appears to be less important for the subjects than head orientation and movement. Although intriguing, such data may merely mean that for chimpanzees, behaviors associated with the act of attending to objects or events may serve to increase the valence of a given social stimuli. Thus, chimpanzees may approach others based on head orientation and movement, or direct eye contact, because these acts trigger underlying positive affect. For example, Brothers and Ring (1992) have distinguished between "cold" and "hot" aspects of theory of mind, noting that a distinction should be drawn between an emotional (hot) interpretation of a given social act versus more cognitive (cold) intentional-based interpretations. If we accept this distinction, it allows for the possibility that chimpanzees and humans could use basically the same social information in responding to shifts in the attention of others, but that only humans reinterpret this behavior within the framework of an intentional stance (for details of this argument, see Povinelli, 1996a; Povinelli & Giambrone, in press; Povinelli & Prince, 1998).

Nonetheless, it is still possible that chimpanzees, as well as very young children, may understand attention as a mental state, but conceive of it less like a mental spotlight emanating from the face and eyes, and far more like a lantern flooding light from the front of the body. If true, this could help to explain why our chimpanzees displayed immediate (Trial 1) success on the back-versus-front treatment, but no other treatment (Povinelli & Eddy, 1996a, Experiment 1), and why frontal orientation seems to hold a higher valence for our subjects than the orientation of the face and eyes (Experiment 4; see also Povinelli & Eddy, 1996c). Such an account would also specify why, in their spontaneous interactions with each other, chimpanzees have been reported to display visually based gestures exclusively in the visual fields of others (Tomasello, Call, Nagell, Olguin, & Carpenter, 1994). However, lower-level explanations of these data are also possible, and so at present this account must remain a speculation—

albeit one that warrants further theoretical and empirical scrutiny.

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