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Correspondence concerning this article should be addressed to Sarah-Jane Vick, Department of Psychology, University of Stirling, Stirling, FK9 4LA, Scotland. E-Mail: sarah-jane.vick@stir.ac.uk

Abstract

The ability of four olive baboons (*Papio anubis*) to use human gaze cues during a competitive task was investigated; the baboons were allowed to remove only the non-fixated one of two simultaneously presented food items. Three baboons successfully learned to exploit the human's head orientation as a cue to obtain a food item, and one individual also learned to use eye direction alone. As the baboons did not receive prior training with gross gestural cues, their performance suggests that the competitive paradigm may be more conducive to gaze monitoring in nonhuman primates than the standard object-choice paradigm. However, the baboons were insensitive to whether the experimenter could actually perceive the food item and therefore use of visual orientation cues may not be indicative of visual perspective-taking abilities in baboons. Performance was disrupted by the introduction of a screen and objects to conceal the food items, and to a lesser degree by the absence of movement in cues presented.

Introduction

Research has shown that animals are sensitive to human visual attention, in as much as behavioral phenomena such as tonic immobility (Gallup, 1972), injury feigning (Ristau, 1998) and flight responses (Hampton, 1994) are influenced by whether or not a nearby human is looking at the animal. However, studies on animals' abilities to co-orient and exploit non-self-directed gaze have been limited to a few species: primarily primates, but also domestic dogs and horses (Anderson, Sallaberry & Barbier, 1995; Call, Hare & Tomasello, 1998; Itakura, 1996; McKinley & Sambrook, 2000; Miklosi, Polgárdi, Topál & Csanyi, 1998; Povinelli & Eddy, 1996a).

Within this domain, the study of primates' abilities to monitor and exploit the gaze information of others is almost exclusively restricted to two experimental paradigms: visual co-orientation and object-choice tasks. These paradigms have produced divergent results. Visual co-orientation with humans or conspecifics has been demonstrated in great apes and several species of monkeys. Thus, nonhuman primates are sensitive to variations in both head and eye orientation in terms of visually inspecting locations congruent with another's gaze (Anderson & Mitchell, 1999; Call, Hare & Tomasello, 1998; Emery et al, 1997; Ferrari et al, 2000; Itakura, 1996; Lorincz, Baker & Perrett, 1999; Povinelli & Eddy, 1996b; Tomasello, Hare & Fogleman, 2001). Co-orienting with another individual's line of regard is undoubtedly advantageous for social animals such as primates; important information regarding predators, food sources and social events, for example, may be acquired through a simple gaze following mechanism (Kummer, 1967). Indeed, this behavioral mechanism is represented at the neurophysiological level with cells in the superior temporal sulcus and amygdala specialized for processing information concerning gaze (Perret et al, 1985; Campbell et al, 1990; Emery, 2000).

The second main experimental paradigm, the object-choice task, has revealed some limitations of gaze following by primates. This task requires the subject to use experimenter-given cues, such as pointing or looking, to locate a hidden food item in, under or behind one of two objects presented. A distinction has been made between a tendency to co-orient so that both individuals are oriented in the same direction, thereby increasing the likelihood of discovering a common object, and an ability to accurately focus on the object of another's gaze (e.g. joint attention; Moore & Dunham, 1995). Ostensibly, the object-choice task could be solved using simple co-orientation as looking where the experimenter looks should heighten the probability of choosing the first object encountered and retrieving the food item. This does not seem to be the mechanism invoked by the object-choice task; despite their ability to track gaze, primates often have serious difficulties in mastering the object-choice task.

Although some great apes and monkeys tested on object-choice are able to use experimenter-given cues up to and including eye direction alone (Itakura & Tanaka, 1998; Vick & Anderson, 2000), there are complicating factors, including the identity of the cue-giver (Itakura et al, 1999; Vick & Anderson, 2000) and the extent of early social experience with humans (Call et al, 1998; Itakura & Tanaka, 1998; Peignot & Anderson, 1999; Povinelli et al, 1999). In addition, Call et al (1998) suggested that the type of object used to conceal food items may influence performance and that the experimenter should actually be able to perceive the food item while cueing. However, during an object-choice task, chimpanzees' choices of object were relatively insensitive as to whether the experimenter was accurately oriented towards an object, let alone perceiving the food item (although they did visually co-oriented with an experimenter looking above the container; Povinelli et al, 1999; but see Tomasello et al, 1999, for more sophisticated performance within a gaze following paradigm). Moreover, for monkeys, explicit training in object-choice gaze exploitation may be required; monkeys are usually given prior experience with manual gestures such as pointing before they master gaze orientation as a cue (Anderson, Sallaberry & Barbier, 1995; Anderson, Montant & Schmitt, 1996; Itakura and Anderson, 1996; Vick & Anderson, 2000).

It is conceivable that the apparent difficulty with the object-choice task is due to the fact that it is based on co-operation between the experimenter and subject; primates (or at least those with limited human contact) may be less likely to demonstrate their gaze monitoring abilities in such a context (Call et al, 2000). That is not to say that nonhuman primates fail to see human experimenters as interactants; they readily respond to human eye contact with appropriate behavioral responses (Exline & Yellin, 1969; Kummer, Anzenberger & Hemelrijk, 1996; Thomsen, 1974). However, the object-choice task may neglect an important point: for nonhuman primates, access to resources is usually more a matter of competition than co-operation (Byrne & Whiten, 1988; Coussi-Korbel, 1994; Dawkins & Krebs, 1978; Peláez, Gil-Burmann & Sánchez, 2000; Schaub, 2000). Viewed from this perspective, the interaction with a human experimenter sitting behind (and effectively controlling access to) food is intrinsically a competitive one (Hare, 2001; Ristau, 1998)

Thus, an alternative way to study gaze monitoring is to adopt a competitive approach. Kummer et al (1996) investigated long-tailed macaques' use of visual perspective-taking in order to conceal themselves from a human experimenter and gain access to a desired resource; the monkeys failed to engage in effective hiding behaviors (and hence demonstrate effective gaze monitoring). Nevertheless, nonhuman primates may display their abilities to monitor the visual orientation of others more readily in other situations characterised by competition over resources, as suggested in reports of tactical deception (Byrne & Whiten, 1988), and in patterns of social monitoring (Blois-Heulin & Girona, 1999) and behavior (Hare et al, 2000; Hare, Call & Tomasello, 2001) during food competition. As Hare (2001, p

721) states: ‘the lives of all primates are dominated by intense competition with conspecifics. All environments have finite supplies of resources on which survival and reproduction are dependent.... In species as diverse as ring-tailed lemurs, squirrel monkeys, and chimpanzees the majority of the day is spent in the company of one’s most intense competitors: conspecifics.’

The present study was derived from the object-choice approach, but the task was modified to become competitive rather than co-operative. Instead of being required to follow the experimenter's gaze in order to locate and select a baited object, the baboons needed to monitor the experimenter's visual orientation in order to take the one of two visible food items presented that the experimenter was not looking at. Note that this also means that the task could not be performed on the basis of simple gaze following as this would lead to an incorrect response. As this experiment aimed to improve approximation of naturalistic competition over food, the baboons were not explicitly trained to monitor the experimenter’s gestures as in previous object-choice studies with monkeys, instead they were simply presented with gaze: head and/or eye orientation. A previous study presented baboons with these same cues in a standard object-choice task without any scaffolding with manual cues (Vick, Bovet & Anderson, 2001). The baboons did not exploit either head or eye gaze, although one baboon showed signs of learning to respond to head direction as an information source after several hundred trials. Thus, the present study allows a within-species comparison on the two tasks; will a competitive context be more conducive to using another’s gaze?

Methods

Subjects

The monkeys were four adult olive baboons: two captive born males, Sylvestre (18 years old), and Balthazar (15 years old), and two females, Ida, (6 years old) and Green (7 years old, wild born). The baboons were housed in 2 groups (one with 9 members and the other with 7 members) in indoor/outdoor quarters (35 m² each) at the CNRS Station de Primatologie in Rousset-sur-arc, France. All the baboons except Green had previously been tested on a categorisation task (Bovet & Vauclair, 1998). Balthazar and Ida had been tested on the object-choice task 12 months before the present study commenced (neither had performed at above-chance levels; Vick, Bovet & Anderson, 2001). They received their daily food ration (fruit, dried pellets and vegetables) at the end of daily training and testing. Standard food items (pieces of fruit) and treats (nuts, raisins, cereals) were used during test sessions.

Apparatus

The apparatus consisted of a wooden tray (60cm x 40cm) which rested upon a table (50cm x 30cm x 40cm). The tray’s midline was marked from front to back and a small square (2cm x 2cm and 10cm in

from the front and side of the tray) was marked on either side of the midline. A chronometer was used to signal 5-second intervals.

Procedure

The tray was placed about 50cm away from the enclosure fence for baiting. The experimenter (SJV) sat in a neutral posture behind the tray, and while fixating on the centre of the tray, placed a food item on each of the two squares simultaneously (the food items were the same type and size within each trial). The experimenter's head and eyes were approximately 50cm from the food items. The experimenter then presented the cue condition for 5-seconds and then, maintaining the cue, pushed the tray against the mesh wall of the enclosure to allow the baboon to respond.

Baboons were tested in the presence of other group members, although any individuals of higher dominance rank being restricted to the indoor area during the testing sessions. Each baboon was presented with 30-trial sessions with a baseline session preceding each block of five cue-condition sessions. For baseline sessions, the experimenter looked down at the midline at the near-side of the tray, while for cue conditions she oriented head and/or eyes towards one of the food items. The 'correct' side was the side that the experimenter was *not* oriented and/or looking towards. The baboons responded by reaching towards one of the food items. If they reached towards the non-fixated side they were permitted to take the food item and consume it. However, if they reached for the side that was oriented towards, the tray was quickly pulled away so that they could not take the food item and the experimenter then pretended to consume the food item.

The inter-trial interval was approximately 30 seconds. Both sides were oriented towards an equal number of times, with the constraint that no more than three consecutive trials were allowed in which the cue was presented to the same side. Two baboons commenced with a head and eye cue condition (Balthazar and Ida) while the other two (Sylvestre and Green) were first presented with eye gaze alone as the cue. Each baboon continued in a given condition until they reached a 'mastery' criterion of 80% correct for two consecutive sessions within a 5-session block (which they then completed) or until they had completed 25 sessions; the baboons were then presented with the alternative cue condition. One to three sessions were conducted daily with a minimum of 15 minutes interval between sessions.

Results and Discussion

Individual performances are illustrated in Figures 1a-b and 2a-b. The baboons reached for one of the two food items on every trial, showing their full participation in the competition for food. Performance was tested against chance response levels using binomial tests. Only one baboon (Ida) reached the

mastery criterion of 80% correct in the first cue condition presented; in the head and eyes condition she was above chance performance in four of the five initial sessions, $p < 0.05$, and at 80% or above for all of sessions 6-10, all $p < 0.01$ (see Figure 1a). Balthazar, presented with the same cue condition, performed consistently above chance (with the exception of one session) from session 11 onwards, $p < 0.05$, but he failed to meet the mastery criterion of 80% correct (see Figure 1a). In contrast, both subjects presented with eye direction alone as a cue were at chance levels throughout the 25 sessions (with the exceptions of one cue and one baseline session for Sylvestre, see Figure 2b).

In their second conditions two of the four baboons reached mastery criterion. Ida successfully mastered the eye direction only condition after 11 sessions (see Figure 2a), while Green reached criterion in the head and eye orientation condition after 7 sessions, though she performed significantly better than chance from session 3 onwards, $p < 0.05$ (with the exception of session 6, see Figure 1b). Balthazar and Sylvestre failed to reach criterion in the eye direction only and head and eyes orientation condition, respectively. Although Sylvestre did perform at above chance levels, $p < 0.05$, in eight out of ten sessions from session 6 onwards, he did not maintain a consistent level of performance thereafter (see Figure 1b). These results establish that the competitive approach is an appropriate method for assessing gaze monitoring; this is the first evidence of baboons demonstrating an ability to master gaze cues in a problem-solving interaction.

Immediately following initial testing the performance of three of the baboons was further explored. Supplementary testing with Sylvestre revealed that he was able to master a point and gaze (head and eyes) cue condition, avoiding the indicated food item with significant regularity from the second session, $p < 0.05$, and reaching an 80% avoidance level by session 7. Thus, Sylvestre's previously poor performance was not attributable to a lack of motivation. As he reached mastery criterion with pointing as a cue, he was again presented with only the experimenter's head and eyes oriented towards the food item (10 sessions), but his performance immediately fell to chance levels (mean 60.3% correct); even after 300 trials he was unable to respond on the basis of head and eye orientation.

As Green had mastered the head and eye cue condition, she was again presented with an eyes only cue in order to exclude order effects as an explanation for her superior performance in the former condition. After 25 sessions (750 trials) she remained at chance levels (mean 55.9% correct).

To summarize: one baboon mastered both the eye direction alone and head and eye orientation cues, one mastered head orientation but not eye direction and two failed to reach mastery criterion levels of performance in both conditions, although one of these did perform consistently above chance levels when presented with head and eye orientation as a cue. Combined head and eye orientation appears to be a more effective cue than eye direction alone; two baboons reached the mastery criterion and a third

performed consistently above chance when head orientation was a component of the cue, while only one baboon mastered the eyes only cue condition. Moreover, although Ida mastered both conditions, she did so more rapidly in the head and eyes orientation condition (in session 6 compared to session 12 for eye direction alone). A second baboon (Green) was unable to master the eye gaze cue only, even after receiving a total of 1500 trials. These results converge with other evidence that monkeys more readily use head direction than eye direction alone as experimenter-given cues in object-choice tasks (Anderson, Sallaberry & Barbier, 1996; Itakura & Anderson, 1996; Vick & Anderson, 2000) and perhaps also within a broader gaze following paradigm (Ferrari et al, 2000; Vick & Anderson, in prep).

The results of this experiment demonstrate that olive baboons are able to learn to use the gaze cues of a human experimenter without requiring prior training with more explicit gestural cues. While this could suggest that baboons are more adroit at reading gaze than other species, for which manual cues appear to be facilitating (Itakura & Anderson, 1996), this seems an unlikely explanation. A previous object-choice study with olive baboons, which did not incorporate scaffolding in the form of manual cues, resulted in only one of four baboons learning to use (but not master) an experimenter-given cue (head orientation) after 700 trials (Vick, Bovet & Anderson, 2001).

Study 2

Introduction

Given that three of four baboons demonstrated an ability to use head and eye orientation as cue in Study 1 (two meeting the mastery criterion of 80% and a third performing consistently above chance levels), we set out to further explore this ability. The first manipulation concerned the role of motion in head orientation as a cue. Object-choice tasks have typically presented static gaze cues (Anderson, Montant & Schmitt, 1996; Anderson, Sallaberry & Barbier, 1995; Itakura & Anderson 1996) and it could be that the presence of movement facilitated the exploitation of cues in the competitive situation used in Study 1. Call et al (2000) have proposed that motion may enhance performance by acting both as an ‘attention getter’, emphasizing the experimenter’s actions and providing directionality. However, the addition of movement to head and/or eye orientation cues in an object-choice task with chimpanzees did not improve performance (Povinelli, Bierschwale & Čech 1999; but see Povinelli & Eddy, 1996b, for contrasting evidence using a trainer-choice task). Thus, it remains unclear whether motion facilitates the reading of visual orientation cues.

The second manipulation attempted to determine the baboons’ level of understanding of looking behavior; although only one baboon used eye direction explicitly, was there any evidence of a more implicit influence of the eyes (Moore, 1999) and also, how accurate were the baboons in discerning the focus of gaze? While all but one of the baboons were unable to compete effectively on the basis of eye

gaze direction alone, it may be that the baboons would be sensitive to a grosser cue concerning the role of eyes in visual orientation, that is, whether or not the eyes were open or closed (Corkum & Moore 1995; Povinelli and Eddy 1996b). In terms of actual focus of gaze, it has been proposed that a 'high level' understanding of gaze predicts that subjects should respond differentially according to whether an experimenter is looking at or above an object. A 'low level' model, based on more general co-orienting responses to grosser behavioral indices, would not predict such accuracy in identifying the target of another's gaze (Povinelli, Bierswale & Čech 1999).

The final manipulation was included to identify possible sources of monkeys' difficulty with the typical object-choice task. Is competition more conducive to cue-reading or is the difficulty in object-choice at least partially due to other features of the procedure? For example, might the use of objects and a screen somehow distract the baboons from the task of monitoring experimenter-given cues? There are several ways in which the introduction of screen and objects could change the task for the baboons. For example, concealing the food items might alter the motivational salience of the situation (Boysen & Bernston, 1985). In addition, it has long been known that introducing a screen during delays diminishes performance on delayed-response tasks (Fletcher 1965); the screen and objects might simply increase the complexity of the task and distract from cue-reading.

Methods

Subjects and Apparatus

Three of the baboons tested in Study 1 were tested: Balthazar, Green and Ida. The basic apparatus was the same as that used in Study 1. Additional items were: a cardboard screen (100 x 80cm) and two identical yellow plastic cups (6cm diameter x 6cm high).

Procedure

Four consecutive sessions were conducted with each of the three new manipulations (Movement, Cue and Objects), with baseline sessions separating each of these blocks. In all sessions, subjects were presented with ten trials of the previously mastered head and eye condition, pseudo-randomly mixed with ten each of two new trial types; that is, there were 30 trials a session with the three experimental conditions presented in a randomised order.

In the Movement sessions, in addition to standard cue trials the baboons were presented with a static cue: following the usual baiting procedure, a hand-held screen (100cm x 80cm) was interposed between the experimenter and the baboon to conceal the movement of the experimenter's head or eyes towards one of the items, the screen was then removed and the trial proceeded as previously. To control for any effects of simple introduction of the screen, a third trial type (movement and screen) was

included which incorporated the screen as above but the experimenter did not move her head or eyes until after the screen was removed, producing a standard trial in which the screen was irrelevant.

In the Cue sessions, two novel types of trial were presented; an eyes closed condition, with the head oriented as in control trials but with the eyes closed before the head was turned, and a 'general direction' condition in which the experimenter oriented her head and eyes to the side but upwards (about 30 degrees from the neutral head position) instead of down towards the food item. As the experimenter was not looking at the food item in either of these new trial types, she maintained the cue position for 5 seconds after presenting the tray and the baboon's choice of food item was noted. Thus, the baboons received a reward regardless of their choice of food item.

In the Objects condition, two identical containers were used to conceal the food items; baiting was done as in standard trials and then the two cups were placed over the food items. For half the trials (objects only), the trial then proceeded as in control trials with the baboon simply having to move the object in order to retrieve the food item (which they readily did), while for the remaining trials (objects and screen) a screen was introduced once the cups had been put in place, held in place for 5 seconds and then removed before the trial continued.

Results and Discussion

Movement. As can be seen in Figure 3, overall performance remained high in the standard cue condition (mean 85%; all individuals $p < 0.05$), but deteriorated in both the static cue and movement plus screen conditions (means 65.8% and 72.5%, respectively). A Friedman's test indicated a marginally non-significant effect of condition, $\chi^2_F = 5.64$, $p = 0.06$. Consideration of individual scores revealed that while performance deteriorated when the cue was static (to chance levels for two of the three baboons, 22/40 and 21/40 for Balthazar and Green, respectively; Ida, 36/40, $p < 0.01$), there was also a decrease in response to the introduction of the screen even if movement was retained, although performance did remain above chance levels for two baboons and approached significance for the third (Balthazar, $p < 0.05$, Green, $p = 0.078$, Ida, $p < 0.01$). That is, although the screen diminished performance levels whether the cue was static or dynamic, the absence of motion led to a greater deterioration in performance.

Cue-type. Overall, the baboons performed significantly above chance in the standard cue condition (mean of 79%, all three individuals were above chance performance, $p < 0.05$) as well as in both of the new conditions: eyes closed (mean 74.2%, individuals: $p < 0.05$, $p = 0.078$ and $p < 0.01$ for Balthazar, Green and Ida, respectively) and looking above (mean 73.3%, individuals: $p < 0.01$, $p = 0.078$ and $p < 0.01$, for Balthazar, Green and Ida, respectively). A Friedman test showed no significant

effect of condition: the baboons continued to respond to the head orientation cue regardless of whether the eyes were open or closed and also when the experimenter was not directly looking at the food item, $\chi^2_F = 0.055$, $p = 0.76$. As the baboons were able to take either of the food items on the tray, a Friedman's test was used to assess whether the baboons learned across sessions that the experimenter was not monitoring the food items. The results showed no effect of session on performance in these conditions (eyes closed: $\chi^2_F = 3.96$, ns; looking above: $\chi^2_F = 3.0$, ns).

Objects. Performance in the standard cue condition was above chance for all three baboons (mean 81.6%; for all individuals, $p < 0.05$) but overall performance showed a considerable decrease in both the objects and objects plus screen conditions (means 72.5% and 68.3%, respectively). A Friedman's test showed a near-significant effect of condition, $\chi^2_F = 5.64$, $p = 0.06$. Analysis of individual performances revealed that with both the introduction of the objects and the objects plus screen, performance remained above chance levels for both Green and Ida, $p' < 0.01$, but only approached significance for Balthazar in both conditions, $p = 0.078$. An analysis of performance across sessions addressed possible novelty effects, but the baboons showed no significant change across the four sessions (objects: $\chi^2_F = 2.78$, $p = 0.43$; objects and screen: $\chi^2_F = 2.52$, $p = 0.47$).

The results of Study 2 suggest that although the baboons had learned to take the experimenter's head orientation into account when performing the competitive task, their performance was diminished by procedural modifications including concealing the food items with objects and a screen, and, to a lesser extent, by omitting movement from the cue. Previous negative findings for monkeys presented with gaze cues may therefore reflect the methods used in the object-choice task as much as an inability to use the cues themselves. For example, successful performance following training may at least partially reflect habituation to the objects and screens used, although as performance in the present study did not improve across sessions this appears more than a mere novelty effect.

The addition of movement may make gaze cues more salient, at least for head orientation, suggesting that presentation of static cues may also impede cue-reading by nonhuman primates. It has been proposed that changes in head direction may be a more effective cue (than eye gaze) because they provide a stronger motion transient (Hood, Willen & Driver 1998). Interestingly, the addition of movement within this competitive paradigm could not enhance performance merely by eliciting visual co-orientation with the experimenter (as might be the case in an object-choice task). Instead, head movement simply made the direction of the head more salient for the baboons (see also Call, Agnetta & Tomasello 2000).

The results of the cue manipulations are noteworthy: the baboons continued to respond according to previously learned rules when the experimenter could not see the food item, that is, when the eyes were closed and even the orientation of the head itself (or eyes in Ida's case) was not aligned with one of

the food items. It is conceivable that the baboons simply continued to respond in a manner that they knew to be successful. Even if they were aware of the experimenter's eyes being closed or that the head was oriented above rather than towards the food, they knew from past experience that choosing the food item not aligned with the experimenter's head orientation was a guaranteed strategy for success. However, the baboons failed to learn from their occasional 'errors' that food items could also be removed from the side congruent with head orientation in over half the trials presented. Overall, it appears that the baboons were responding on the basis of past experience and not making any relevant assessment of the experimenter's visual orientation (as also suggested by Povinelli & Eddy, 1996b). Alternatively, the lack of sensitivity to eyes could also be due to the availability of head direction. That is, baboons may be sensitive to whether the eyes are open or closed, but not within a context where head direction is providing directional information (Moore, 1999). However, two of the three baboons also failed to respond to eye gaze when this was the only cue presented, suggesting that head orientation might simply be a more salient cue than eye direction.

General Discussion

The results of these studies suggest that while primates may co-orient with others as a means of locating important events or objects, they are also sensitive to the gaze cues of others on another level, namely, that they can exploit this information competitively in certain circumstances (see also Byrne & Whiten, 1988; Hare, 2001). As with visual co-orientation, such a skill may be the result of simple associative learning; for example, primates may learn that head orientation is a good signal of whether or not a dominant individual is likely to become aggressive over access to food or mating opportunities. As Cheney & Seyfarth (1991, p 193) state, modifying behavior in response to other individuals' orientation and direction of gaze 'certainly demands that monkeys recognise that attentiveness can strongly affect actions,' but it does not require any appreciation of the underlying mental states of attention.

The two baboons that quickly learned to exploit the experimenter's visual orientation, at least as indicated by head orientation, were females. Possibly, the males acted less upon gaze cues because they were less accustomed to losing competitions for resources; in this captive environment a single adult male can enforce exclusive access to receptive females and priority of access to food. Alternatively, it has been suggested that females perform better on delayed-response problems because they are less distractable than males, and this may offer some explanation for the gender differences observed (Fletcher, 1965). It would be interesting to consider responsiveness to gaze cues as a function of social status in other contexts. While previous research has underlined the importance of the 'attentional structure' of groups (Chance, 1967; Watts, 1998), there may also be some relationship between gaze

monitoring and social hierarchy (see Blois-Heulin & Girona, 1999, for patterns and targets of looking relative to rank in a species of Old World monkeys). Lower ranking individuals may gauge the visual orientation of dominants and thus assess the risk of approaching desirable social partners or food items, for example (Hare, Agnetta & Tomasello, 2000).

The results of this study converge with those obtained using a standard object-choice approach in that the baboons responded more readily to head orientation than to eye direction alone (Anderson, Montant & Schmitt, 1996; Itakura & Anderson, 1996; Peignot & Anderson, 1999). Furthermore, during supplementary testing with Ida using a combination of head and eye cues, she preferentially responded to head direction when this conflicted with eye gaze, as also demonstrated in capuchin monkeys performing the object-choice task (Vick & Anderson, 2000). It is possible that monkeys simply learn to respond to arbitrary cues in order to solve the problem presented (Povinelli & Giambone, 2000). That is, they learn head or eye direction as a cue to respond to the appropriate side without any appreciation that these are indicators of another's visual orientation *per se* (Tomasello, Call & Hare, 1998); as head direction is a more obvious cue, this association may be more readily learned. Alternatively, the advantage for head over eye direction cues may reflect an underlying tendency to attend to this form of cue; for many of species of nonhuman primates, head orientation may be a reliable signal of another individual's visual orientation (see Kobayashi & Koshima, 1997; 2001).

Whatever the reason underlying the greater salience of head orientation as a cue, it is important to note that the baboons did not demonstrate an appreciation of the actual focus of the experimenter's gaze; a similar finding has been reported in chimpanzees (Povinelli, Bierschwale & Čech, 1999). While these results may offer little support for the view that the baboons were accurately adopting the visual perspective of the experimenter in the competitive task, it is also possible that their responses were simply tempered by their experimental experience. A different experimental design, with non-attending trials integrated from the onset of testing might be illuminating (e.g. Povinelli Bierschwale & Čech, 1999). Also, examining whether monkeys are able to accurately detect the targets of another's gaze and ignore distractor objects, as has been shown in chimpanzees, would be informative (Tomasello, Hare & Agnetta, 1999), as would attempting to distinguish between location-based responding (i.e. gaze following) and object based responding, which would be indicative of joint visual attention (Moore & Dunham, 1995). Specifically, moving previously attended objects to a new location prior to the subject's response might indicate at what level gaze behaviors are processed.

Although the baboons learned to use gaze cues to perform the competitive task without explicit training, it is difficult to ascertain which features of these experiments were conducive to effective cue exploitation. Possibly, the competitive paradigm is more suited to revealing gaze reading than the more frequently used object-choice paradigm (Hare, 2001), but the results of Study 2 suggest that the use of

screens and containers, both integral aspects in the object-choice task, may also hinder cue reading. In other words, it could be that the modified task simply had fewer sources of information (such as objects) to be processed in order to solve a discrimination task (see Hare, Agnetta & Tomasello, 2000; Povinelli & Giambone, 2000). Counterbalancing the order of presentation of an objects and no objects condition within the competitive paradigm might help clarify this issue.

In conclusion, the object-choice paradigm may not be the most appropriate means of assessing nonhuman primates' abilities to assess the visual co-orientation of other individuals. Performance on the object-choice task does not stem directly from a tendency to co-orient with others; although monkeys readily co-orient with other individuals (Anderson & Mitchell, 1998; Emery et al, 1997; Ferrari et al, 2000; Tomasello, Hare and Fogleman, 2001) they may require explicit training to master tasks which could be performed on the basis of co-orientation. The present study has identified features of the object-choice task that may hinder effective cue reading: the use of objects and a screen disrupted the performance of baboons already experienced at using experimenter-given cues to solve a task, and the presentation of static cues may also impede performance. While it is difficult to draw conclusions regarding the importance of the competitive rather than co-operative nature of the task used here, the baboons learned to make use of experimenter-given cues in competition without the need for explicit training, and one individual did so fairly quickly. Finally, unlike the object-choice task, the competitive task could not be solved on the basis of a direct co-orienting response, that is, any learned or reflexive tendency to co-orient with other individuals would not have directly facilitated performance in this competitive task. Thus, further exploration using complementary approaches to studying gaze monitoring abilities in nonhuman primates are required before strong conclusions regarding comparative abilities may be drawn.

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Figures

Figure 1: Performance in the head orientation condition a) Ida and Balthazar b) Green and Sylvestre

B represents a baseline session. Open data points represent above chance performance ($p < 0.05$). The solid horizontal line represents chance performance; the dotted horizontal line represents the 80% correct level.

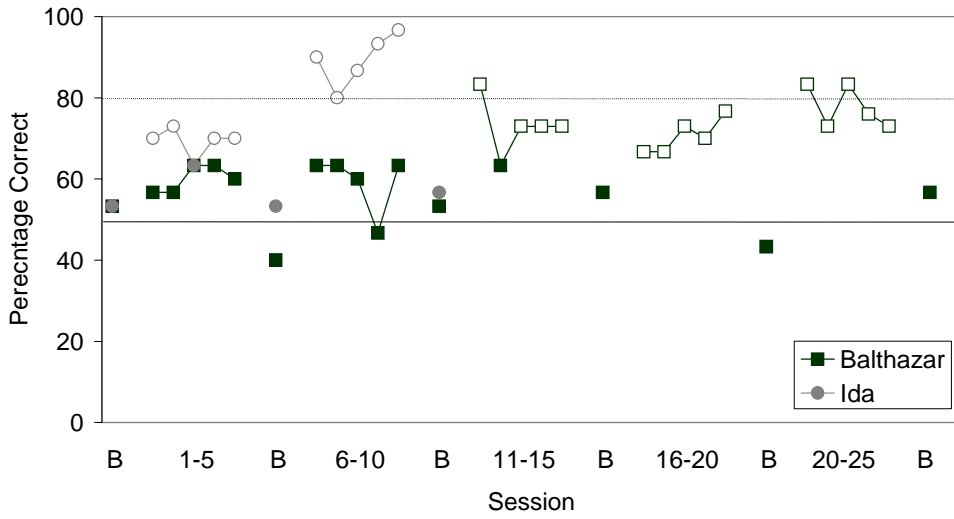
Figure 2: a) Performance in the eye direction only condition a) Ida and Balthazar b) Green and Sylvestre

B represents a baseline session. Open data points represent above chance performance ($p < 0.05$). The solid horizontal line represents chance performance; the dotted horizontal line represents the 80% correct level.

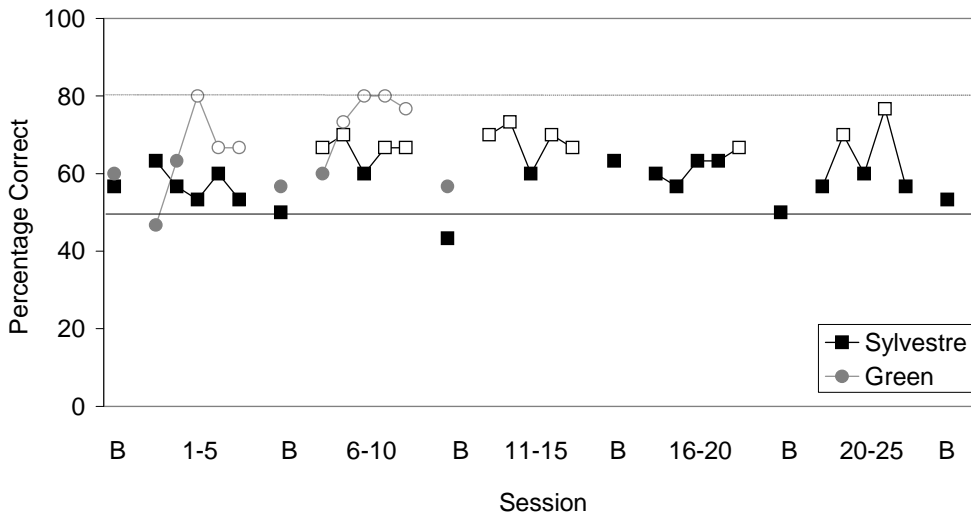
Figure 3: Means (and SEM bars) for performance in Movement, Cue-type and Objects conditions (Study 2).

The dotted horizontal line represents chance performance (50%).

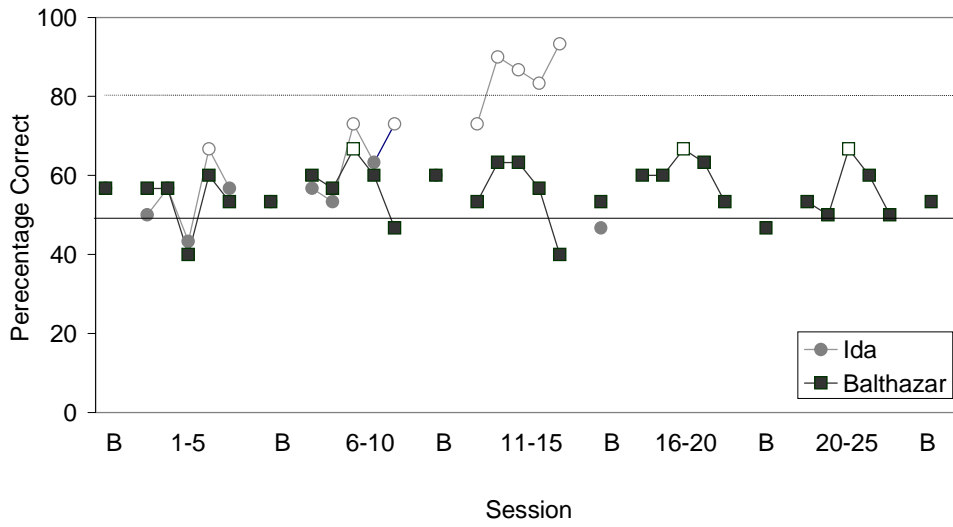
a)



b)



a)



b)

