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PAPER

Carryover effect of joint attention to repeated events in chimpanzees and young children

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Abstract

Gaze following is a fundamental component of triadic social interaction which includes events and an object shared with other individuals and is found in both human and nonhuman primates. Most previous work has focused only on the immediate reaction after following another's gaze. In contrast, this study investigated whether gaze following is retained after the observation of the other's gaze shift, whether this retainment differs between species and age groups, and whether the retainment depends on the nature of the preceding events. In the social condition, subjects (1- and 2-year-old human children and chimpanzees) witnessed an experimenter who looked and pointed in the direction of a target lamp. In the physical condition, the target lamp blinked but the experimenter did not provide any cues. After a brief delay, we presented the same stimulus again without any cues. All subjects looked again to the target location after experiencing the social condition and thus showed a carryover effect. However, only 2-year-olds showed a carryover effect in the physical condition, 1-year-olds and chimpanzees did not. Additionally, only human children showed spontaneous interactive actions such as pointing. Our results suggest that the difference between the two age groups and chimpanzees is conceptual and not only quantitative.

Introduction

By the end of their first year, human infants become sensitive to information specifying where others are looking. The ability to follow the gaze of other individuals is a critical component of joint attention, defined as looking toward the object of others' attention. Infants show a specific developmental trajectory in this ability (see Moore, 2008). In this first year, human infants follow their mother's gaze to the appropriate side (e.g. Scaife & Bruner, 1975), at first when there are objects already in their immediate field of view (e.g. D'Entremont, Hains & Muir, 1997), and later even when objects are outside their immediate field of view (e.g. Corkum & Moore, 1995). By the beginning of the second year, infants will follow their mother's gaze towards particular objects even when various objects are present, and between 12 and 18 months they can direct their attention to objects that are located behind them or in containers (e.g. Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Moll & Tomasello, 2004). Joint attention is considered by some to be an early social cognitive ability leading to the later development of the ability to infer others' mental states (cf. Baron-Cohen, 1995; Tomasello, 1995).

However, eye-gaze is not the only cue to another's focus of attention. The orientation of the whole head, body, and hand (e.g. pointing) are similarly good indicators of attention and interest, and are used in our daily interactions with others. Pointing in particular is considered an important component of joint attention as an indicator of particular objects, locations, or events. At about 12 months, infants begin to follow pointing to distant locations (Butterworth & Jarrett, 1991; Desrochers, Morissette & Ricard, 1995; Lempers, 1979; Leung & Rheingold, 1981; Murphy & Messer, 1977).

Gaze following is also found in a number of nonhuman primates. The use of gaze shifts as social cues has various evolutionary advantages. For instance, gaze shifts may index the location of predators, dominants, potential mates or food sources. Several field studies suggest that primates follow the gaze of conspecifics (e.g. Chance, 1967; Menzel & Halperin, 1975; Whiten & Byrne, 1988). A number of laboratory studies have also investigated gaze following in nonhuman primates.

Within a gaze-following task paradigm, various studies with chimpanzees have demonstrated that they follow the gaze direction of other individuals (e.g. Itakura, 1996; Povinelli & Eddy, 1996; Tomasello, Call & Hare, 1998; Okamoto-Barth, Call & Tomasello, 2007; see Emery, 2000, for review). However, interpreting this behavior is not straightforward, as it may represent either a simple reflexive tendency to visually orient in the

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direction of another individual's visual orientation or a more cognitively complex process of knowing that the other 'sees' something. For instance, studies using several different types of barriers have found that chimpanzees actually position themselves so as to gain a good viewing angle at the location to which another individual is looking (Tomasello, Hare & Agnetta, 1999; Okamoto, Tanaka & Tomonaga, 2004; Bräuer, Call & Tomasello, 2005). This type of 'perspective angling' develops at around 12 months of age in humans (Moll & Tomasello, 2004), and has also been documented in chimpanzees and bonobos (Okamoto-Barth *et al*., 2007). Okamoto-Barth *et al*. (2007) reported that chimpanzees and bonobos followed gaze more often when the experimenter looked through a barrier with a window than one without a window. These results, combined with others showing that these species also follow gaze around barriers (Bräuer *et al*., 2005; Povinelli & Eddy, 1996; Tomasello *et al*., 1999), suggest that chimpanzees and bonobos have some understanding of the referential nature of looking. However, the sophistication of this ability in chimpanzees is not as present as in human infants. For instance, in one study (Tomasello, Hare, Lehmann & Call, 2007), a human experimenter 'looked' to the ceiling either with his eyes only, head only (eyes closed), both head and eyes, or neither. Great apes followed gaze to the ceiling based mainly on the human's head direction (although eye direction played some role as well). In contrast, human infants relied almost exclusively on eye direction in these same situations. But the knowledge about how this skill differs between species is still fragmentary.

Most previous work with both human and nonhuman primates has focused on the immediate reaction such as whether subjects followed gaze of others towards a particular target. However, in daily life, our action towards events or objects, which we share with others, is often more of a prolonged interaction about ongoing events. The duration and nature of these gaze-following episodes during interaction has so far not been well investigated. In the context of gaze following, Itakura (2001) reported that human infants (average 11 months old) gazed longer at a stimulus that was blinking or had been pointed at by the mother than a stimulus which was not blinking and had not been pointed at by the mother. When the stimulus was presented a second time (after a delay), infants gazed longer at the stimulus that the mother had pointed at during the earlier trial ('carryover effect'), than at the stimulus that had been blinking in the earlier trial. This result has been interpreted to mean that a social cue (e.g. joint attention episode) captures a child's attention better and for a longer period of time than a non-social cue (e.g. stimulus change episodes/blinking object).

However, why did the infants keep their attention longer for the social cue than for the blinking object? The object which was pointed at was referentially highlighted and the blinking object was saliently (and physically) highlighted. So, looking at objects might have a different meaning depending on whether a cue has an apparent referential meaning or just a physical salience. The question then is whether the social referential nature of pointing (or gazing) carries more conceptual meaning and that is why it keeps children's attention longer than cues of only physical salience. One plausible explanation is that there are developmental stages that were not addressed in Itakura's study (no comparison of age differences was made, the subjects had a mean age of 11 months).

To better understand the development of the gaze-following ability and particularly the way in which gaze cues might be taken to carry meaning extended over time, it is important to know how infant gaze following will change with age and from when they show the carryover effect. We were thus motivated by the following questions: Do 1-year-old and 2-year-old infants display different reactions after following gaze or looking at a physical salient event? If so, when and how does such a difference emerge in human development? For instance, reaction time of looking at the target after following the cues and looking at the same target again after some delay might be different between ages, especially in the case of children, which may carry some conceptual meaning to the event. Moreover, some communicative actions such as spontaneous pointing or task-related vocalization might occur as well. Previous research suggests that infants of 1 year of age already have a motive for sharing experiences with others as psychological agents (e.g. Tomasello, Carpenter, Call, Behne & Moll, 2005). They also begin to produce declarative pointing when they are about 1 year old (Tomasello & Camaioni, 1997). Such skills might be different in a social or physical context.. Additionally, we are also interested in age differences and whether there is any difference between human infants and other primates, such as chimpanzees. Since social signals might carry important information, reactions to social signals might be different from reactions to physical signals.

To that end, the current study modified the paradigm of Itakura (2001) to test two groups of human infants (1-year-olds, 2-year-olds) and adult chimpanzees. In his study, two line-drawing stimuli were presented next to each other on a computer screen, and the infants sat on the lap of their mother to look at the stimuli from the same direction. The mother pointed at one stimulus while making a positive comment; 'Look, it's very cute'. Pointing plus a positive comment from the mother might have a strong influence on the infant about one target stimulus and might affect the result in such a way that children kept their attention fixed for longer on that stimulus (carryover effect) compared to the blink condition. To control for this, we had an experimenter who was the same for all children and chimpanzees subjects, and did not give any verbal action towards the stimuli. Additionally, the experimenter sat facing the subjects, and the stimuli were placed in the view of both subjects and the experimenter. In one condition, subjects

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witnessed a human experimenter look at and point in the direction of a target object. In the other condition, a target object blinked by itself but the human experimenter did not do anything. Following a brief delay after this first phase, we presented the same objects again. Our goal is to shed light on both the ontogeny and phylogeny of reactions after salient events that are highlighted by social and physical cues.

Experiment 1: Human children

In Experiment 1 we first explored if the older children perform like 1-year-old children (Itakura, 2001) in a gaze-following task. To do so, we tested 1-year-olds, and compared their results to a group of 2-year-olds. We modified the methods and test settings from Itakura (2001), increased age groups, number of trials, and measuring where the child first looked rather than looking duration and reaction time of their looking behavior. Additionally, we also scored incidences of task-related communicative actions (such as spontaneous pointing, vocal reactions).

Methods

Participants

Twenty-four children participated in the experiment (1-year-olds, $N = 12$ and 2-year-olds, $N = 12$; 1-year-olds: mean age $M = 14.6$ months, range = 11–18, standard error of the mean (SEM) = 0.75; 2-year-olds: $M = 23.8$ months, range = 23–25; SEM = 0.21). There were an equal number of males and females in each group. The children were recruited by using standard Center for Child Studies' recruiting procedures, and from the database of parents who had previously signed up their children for participation in cognitive development studies at the Center for Child Studies located at the University of Louisiana.

Apparatus and materials

Two identical lamps were used (22 cm × 22 cm × 30 cm). The lamps were mounted on the edges of walls (244 cm × 76.2 cm) in a testing room at the Center for Child Studies (see Figure 1). Each lamp was operated by remote control. When the light fixtures were turned on, the lamps lit up to reveal a picture. Twenty-four pairs of identical images (21.5 cm × 27.9 cm) printed on transparency film were used as stimuli (one for each lamp) and were changed after each trial. The pictures were inserted in the front-slit of the lamp. When the light was turned on, the images became visible. Two standard office chairs (one was rotatable) were used: one for experimenter 1 (E1), and the rotatable chair for the child to sit with his or her parent. Four cameras (two wide angle cameras and two cameras focused on the subject, see Figure 1) were used to record a picture of the experiment and were controlled on a monitor in an adjacent room by the second experimenter (E2). The timing of the experiment and light fixtures were also controlled by E2.

Procedure

Warm-up period. Children visited the Center individually with their parents. Upon arrival, the child played with the experimenters in the waiting room for approximately 10–20 minutes to allow them to become familiar with the experimenters and the environment. During this time, the child's parent read and signed a consent form describing the study. The parent was also given instructions about their participation in the study. Once the child appeared comfortable, he or she and their parent were escorted to the testing room.

Testing. Each trial began with the parent and child in their starting position: seated in the rotating chair, facing the back wall of the room to not see the images on the lamps and preparation of the next trial by E1. E1 was seated in the other chair, facing toward the child and parent.

Testing consisted of three conditions: Control, Blink, and Social. The order of conditions was counterbalanced. Each testing condition consisted of three phases: (a) First presentation phase (Phase 1), (b) Inter-presentation interval, and (c) Second presentation phase (Phase 2) (see Figure 2). Each testing condition had four trials, totaling 12 testing trials per subject. Subjects received a new pair of images on each trial. The 24 image pairs were randomly administered across trials within each subject.

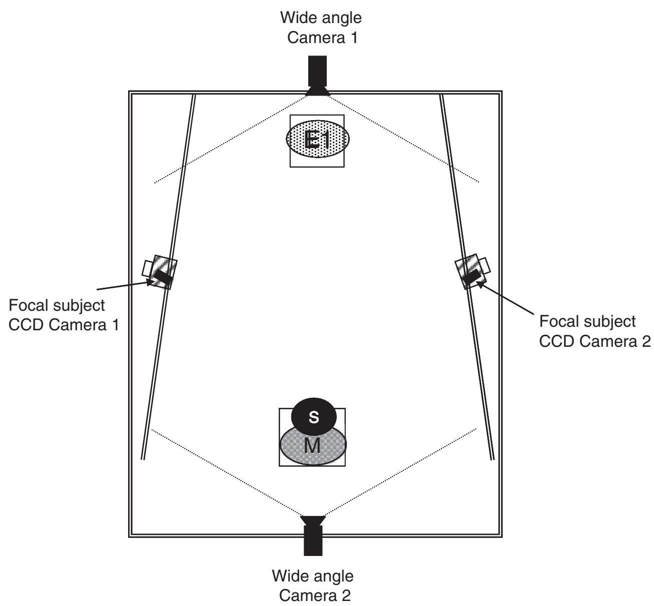

Figure 1 *Aerial view of the experimental setting. 'E1' = experimenter 1, 'S' = subject, 'M' = mother.*

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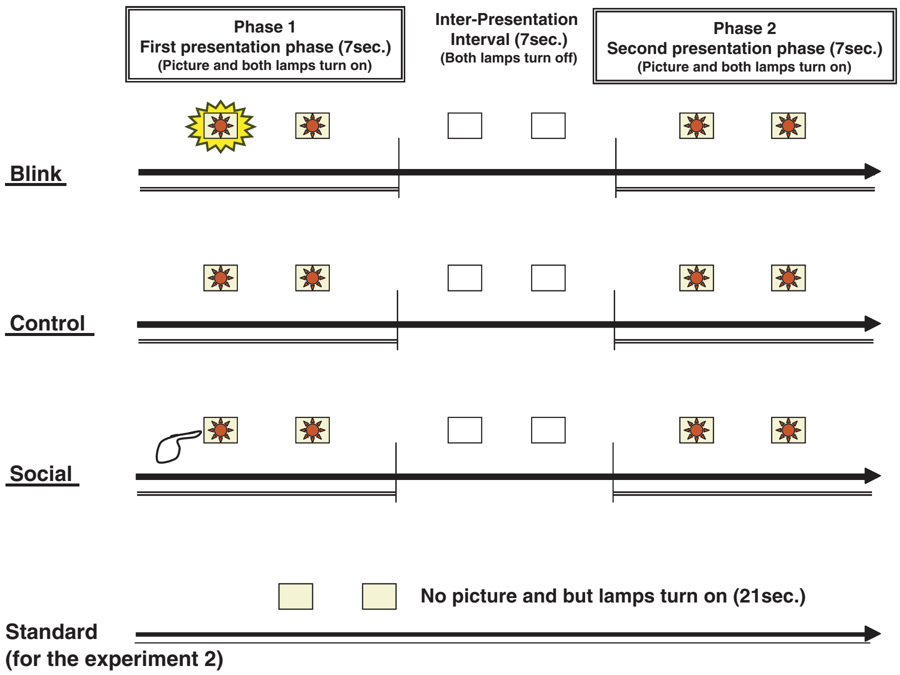

Figure 2 *The flow of the experiment.*

Before each trial, E1 said 'ready', indicating to the parent to turn around and face E1. During all trials, except for trials in the Social condition, E1 faced forward, stared straight ahead to a designated neutral point, and avoided eye contact with the child, and kept her hands on her lap (neutral position). Once the child and parent were into the starting position, E2 began the following sequence per trial:

First presentation phase (phase 1): E2 remotely switched on both lamps, making the pictures visible for 7 seconds, and then switched off the lamps. E2 controlled the duration by using a stopwatch.

Inter-presentation interval (interval): E2 kept the lamps in off-mode for 7 seconds, so that they were not visible to the subject.

Second presentation (carryover) phase (phase 2): E2 switched on both lamps again, making the images visible to the subject, and then turned them off again after 7 seconds.

Once the lamps were turned off, E1 indicated to the parent to turn around with the child to face the opposite side of the room again. Once the parent and child had returned to their starting positions (with their backs turned to E1), E1 changed the images to prepare for the next trial. This sequence was the basic flow of the testing trials and was identical in the *Control condition*.

In the *Social condition*, the basic flow of trials was the same except for phase 1; E1 pointed and looked (turned her head) at one of the two lamps during phase 1 for 7 seconds. During the interval and phase 2, E1 maintained her 'neutral position'.

In the *Blink condition*, the basic flow of the trial was the same except for phase 1. Once both lamps were turned on, E2 caused one of the two lamps to blink (one flash per second) during phase 1. The remaining phases were the same as the control and social conditions. Conditions, directions in which the experimenter pointed, and the locations of the blinking lamp were counterbalanced within subjects. For coding purposes, we specified the stimulus for each condition (see Figure 2). The stimulus (picture-image on the lamp) which was pointed at by the experimenter during phase 1 is referred to as 'blink-target', and the same stimulus (which is no longer being pointed to) is referred to as 'pointed-target' for phase 2. The stimulus which blinked during phase 1 is 'blink-target', and the same stimulus (which is no longer blinking) is 'blinked-target' for phase 2.

Coding

We analyzed the children's behavior based on which lamp they looked at first. These measurements were coded in phase 1, interval and phase 2. For coding, video materials from the two focal subject cameras were used (see Figure 1). The cameras were located at each lamp. That is, if the children looked at the lamp the coder could see the children's face in frontal view (on the video screen from the camera 1). This was judged to be that the child was looking at the lamp (which is located just above camera 1) and was coded as 'looking-left' or 'looking-right' from the coder's (and E1's) perspective. If the child did not look at the camera during the whole trial period (e.g. the child looked at the ceiling, looked at the experimenter, or looked behind them), then this trial were coded as 'no looking'. Additionally, in cases where the subjects showed some spontaneous communicative actions such

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as spontaneous pointing or task-related vocal reactions the incidences and their direction were also scored. The main observer (SB) classified the children's behaviors, according to the categories described above, from the video recordings. To assess inter-observer reliability, an additional coder (CC) watched 25% of all trials and rated the children's behavior after training in coding. The inter-observer reliability was calculated by means of Cohen's kappa. The agreements and kappa results between the observers were 94.8%, $\kappa = .91$.

After coding, we defined as 'carryover' the behavioral sequence in which the child looked during phase 2 at the target stimuli in phase 1 after having looked at the target stimuli during phase 1 (child looked at the targets in both phases). Moreover, we coded the duration (reaction time) from the first cue onset (moment at which the experimenter started to point or the lamp started to blink) to initiation of the child's head turn in phase 1. In phase 2, the duration from the second cue onset (moment at which both lamps turned on in the beginning of phase 2) to initiation of the child's head turn (moment at which the child's head started to turn again) was measured. All durations (phase 1 and 2) were calculated for each cue onset and initiation of head turn. The main observer (SB) used the time display of the video equipment (frame by frame analysis) to assess duration. To assess inter-observer reliability, an additional coder (HR) watched 25% of all video recordings (as above) and rated the children's behavior after training in coding. The inter-observer reliability was calculated by means of Cohen's kappa. The agreements and kappa results between the observers were 88.6%, $\kappa = .84$.

Results

First-look behavior

To clarify the overall picture of comparison of looking behavior between 1- and 2- year-olds, Figure 3 shows the percentage of looking trials for the control, social and blink conditions for both phase 1 and 2 for both age groups.

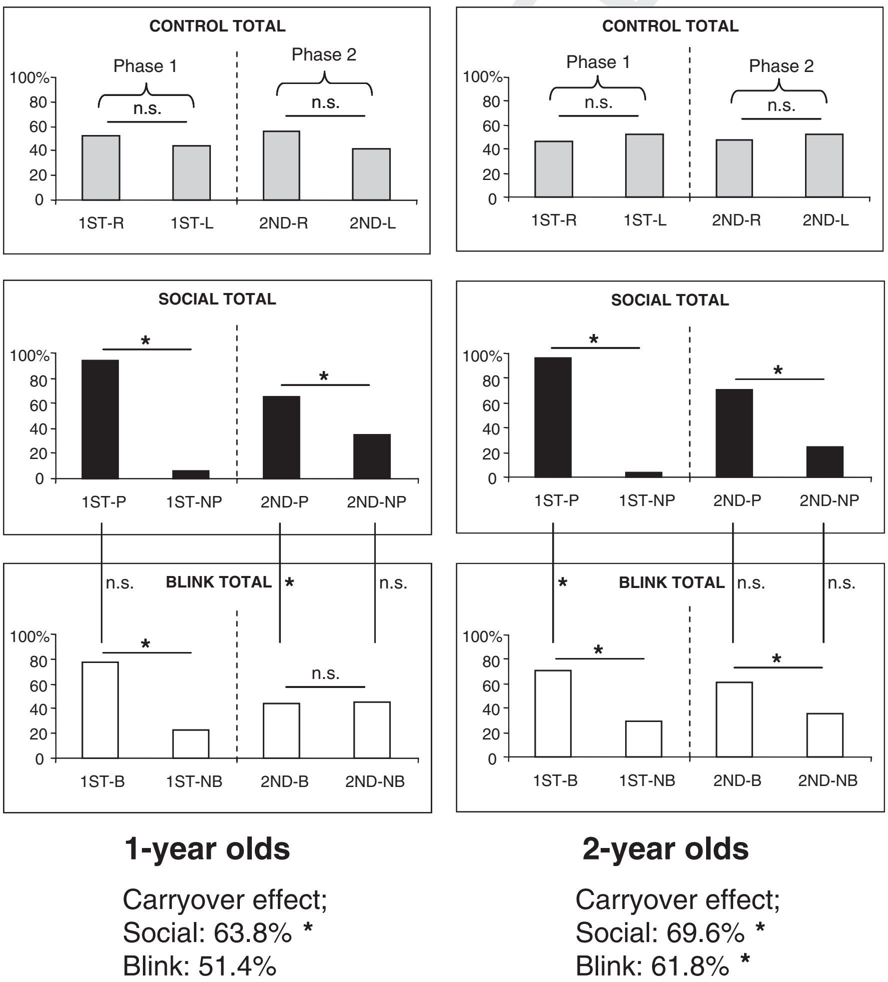

Figure 3 *Average 'looking' responses during phases 1 and 2 for 1- and 2-year-olds. '1ST-R' = right side lamp and '1ST-L' = left side lamp during phase 1. '1ST-P' = point-target stimulus for the social condition (pointing and looking by the experimenter) and '1ST-NP' = non-target stimulus (the stimulus which was not pointed to or looked at by the experimenter) during phase 1. '1ST-B' = blink-target stimulus and '1ST-NB' = non-target stimulus (the stimulus which did not blink) for the blink condition during phase 1. The same abbreviations are used for phase 2 ('2ND-'). Asterisk (*) marks indicate* p *< .05.*

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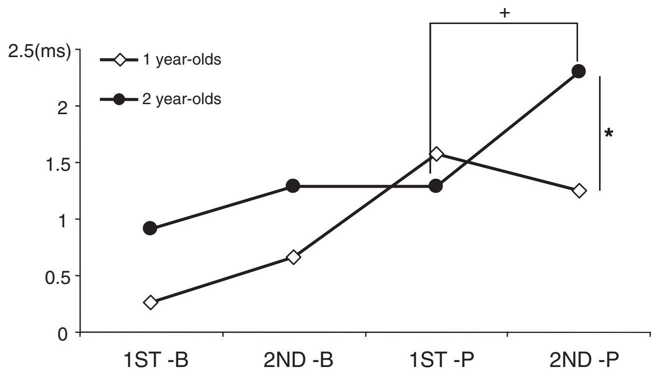

Figure 4 *Average response time during correct response trials (subjects showed 'looking'). '*' mark indicates* p *<. 05. '+' mark indicates p < .10.*

A Wilcoxon signed ranks test (two-tailed) was conducted with first-look and direction of looking. In the control condition, the first-look for both left and right stimuli was almost the same in both phase 1 and 2 for both age groups. No significant difference in first-looks were found between right and left in both phases (1-year-olds: phase 1, $T(11) = -.51$, $p = .61$; phase 2, $T(11) = -.94$, $p = .35$, 2-year-olds: phase 1, $T(11) = -.43$, $p = .67$; phase 2, $T(11) = -.32$, $p = .75$). This result shows that children did not have a bias responding to one particular direction. In the social condition, there was a significant difference between children's first-look towards the point/pointed-targets and the non-targets in both phases. This was true for both age groups (1-year-olds: phase 1, $T(11) = -3.21$, $p = .001$; phase 2, $T(11) = -2.65$, $p = .008$, 2-year-olds: phase 1, $T(11) = -3.32$, $p = .001$; phase 2, $T(11) = -2.75$, $p = .006$). The fact that children frequently looked towards the targets shows that children's looking was affected strongly by the experimenter's actions. Moreover, this behavioral pattern was carried into phase 2 ('carryover effect') in both age groups.

However a different pattern emerged in the blink condition. As in the social condition, both age groups showed a similar behavioral pattern in phase 1. Interestingly, this pattern disappeared in the 1-year-old group but remained in the 2-year-old group (1-year-olds: phase 1, $T(11) = -2.60$, $p = .009$; phase 2, $T(11) = -.12$ $p = .90$, 2-year-olds: phase 1, $T(11) = -2.23$, $p < .05$; phase 2, $T(11) = -2.11$, $p < .05$). That is, 1-year-olds did not show a 'carryover' effect in the blink condition; 2-year-olds did.

Furthermore, we compared looking behavior between the social and blink conditions. In phase 1, even though the 1-year-olds looked at the targets in the social condition frequently, there was no statistical difference between conditions among 1-year-olds ($T(11) = -1.87$, $p = .062$), whereas 2-year-olds showed a more robust behavioral response in the social condition than in the blink condition ($T(11) = -2.28$, $p = .023$). In phase 2, a comparison of children's behavior in both conditions resulted in an age group difference (1-year-olds: $T(11) = -2.33$, $p < .05$, 2-year-olds: $T(11) = -1.52$, $p = .13$), such that in phase 2, 1-year-olds looked more frequently to the pointed-target than to the blinked-target. In contrast, 2-year-olds showed a similar response pattern in both conditions: their looking preference towards both previously highlighted (pointed/blinking) stimuli were kept in phase 2.

Carryover effect

We compared the correlation between first-looks in phase 1 and phase 2 to estimate if looking behavior in phase 1 was carried over to phase 2, and what kind of stimuli influenced the behavior. One-year-olds showed a carryover effect in the social condition but not in the blink condition (Spearman's rank correlation (one-tailed); social condition: 63.8%, rho = .548, $N = 12$, $p < .05$, blink condition: 51.4%, rho = .456, $N = 12$, $p = .068$). Although looking behavior towards the blinked-target and the non-target was not different in phase 2 as we described above, it relatively frequently showed a 'carryover' pattern (51.4%). However, we did not find any statistical support. On the contrary, 2-year-olds showed the carryover effect in both the social and the blink conditions (social condition: 69.6%, rho = .540, $N = 12$, $p < .05$, blink condition: 61.8%, rho = .525, $N = 12$, $p < .05$).

Response time

Since the two age groups showed different behavioral patterns, we analyzed response time during 'correct' responses in which they looked at the target stimulus in each phase (1 and 2). A paired sample t-test was conducted with the duration of each presentation for both social and blink conditions and age groups. There was a significant difference for 1- and 2-year-olds only in the social condition in phase 2 (paired sample t-test: $t(11) = -2.34$, $p < .05$). Comparison between phase 1 and phase 2 in the social condition of 2-year-olds showed a marginally significant difference ($t(11) = -1.96$, $p = .075$). Even though there was no significant difference in

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statistics, as a general trend 1-year-olds responded faster in phase 2 in the social condition compared to the blink condition in which they responded more slowly in phase 2. In contrast, the graph line was reversed in phase 2 in the social condition for both age groups. Two-year-olds showed slow responses in phase 2 in the social condition.

Spontaneous communicative actions by children

We also scored the incidences of spontaneous pointing by children. Table 1 shows for both age groups the percentage of spontaneous pointing in the control, social and blink conditions in phases 1 and 2.

In general, spontaneous pointing was most frequently observed in the social condition in both age groups. A Wilcoxon signed ranks test was conducted with the spontaneous pointing reaction and its direction. In the control condition, the pointing reaction observed for both left and right stimuli was not different between phase 1 and phase 2 for either age group (1-year-olds: phase 1, $T(11) = -1.0$, $p = .32$; phase 2, $T(11) = -1.86$, $p = .06$, 2-year-olds: phase 1, $T(11) = -.63$, $p = .53$; phase 2, $T(11) = -1.34$, $p = .18$). In the social condition, spontaneous pointing was more frequently observed than in the control and blink conditions. Among the 2-year-olds group, there was also a significant difference between children's spontaneous pointing towards the point/pointed-targets and the non-targets in both phases (1-year-olds: phase 1, $T(11) = -1.41$, $p = .16$; phase 2, $T(11) = -1.13$, $p = .26$; 2-year-olds: phase 1, $T(11) = -2.57$, $p < .05$; phase 2, $T(11) = -2.07$, $p < .05$). However, in the blink condition, neither age group showed differential pointing reactions towards the blink/blinked targets and the non-targets in either presentation phase (1-year-olds: phase 1, $T(11) = -1.00$, $p = .32$; phase 2, $T(11) = -.58$, $p = .56$, 2-year-olds: phase 1, $T(11) = -.58$, $p = .56$; phase 2, $t(11) = -1.00$, $p = .32$). Most importantly, both age groups spontaneously pointed more frequently towards the point-targets than the blink-targets in phase 1 (1-year-olds: $T(11) = -2.12$, $p < .05$, 2-year-olds: $T(11) = -2.72$, $p < .05$). This could also be explained by imitation (e.g. Horner & Whiten, 2005) since they had a pointing model in the social condition but not in the blink condition. Moreover, 2-year-olds (and 1-year-olds with marginal significance) spontaneously pointed more frequently towards the point-targets in phase 1 than towards the pointed-targets in phase 2 (1-year-olds: $T(11) = -.29$, $p = .56$, 2-year-olds: $T(11) = -2.06$, $p < .05$). These results suggest that the spontaneous pointing was triggered by seeing the experimenter's pointing action. Spontaneous pointing was also frequently accompanied with looking at the experimenter and the lamps alternately.

Furthermore, although they were not quantitatively measured we also observed children's vocal reactions. This was observed more in the 2-year-olds and in the social condition in phase 1, and is consistent with the other results. Given that 2-year-olds were more linguistically and verbally mature than 1-year-olds, this finding is, perhaps, not surprising. The common type of verbalization was naming the stimulus (e.g. 'it's a dog!'). During phase 2, some children also pointed to the previously pointed stimulus and said 'that side!' to the experimenter (note that the experimenter was not doing anything in phase 2). Vocal reactions were also often accompanied by spontaneous pointing and watching the experimenter and the lamps alternately.

Discussion

Both 1-year-old and 2-year-old children looked to the stimulus the experimenter pointed to or to the stimulus that blinked in phase 1. Looking continued in phase 2 of the social condition (pointing) for both age groups. And whereas 2-year-olds continued to look in phase 2 of the blinking condition, 1-year-olds did not. The performance of 1-year-olds supports the finding from Itakura (2001) in which younger children (only around 1 year old (9–13 months) children were tested in Itakura's study) looked longer at the stimuli pointed to by their mother but not to the stimuli that blinked. Our finding on 1-year-olds also showed the carryover effect which represents an effect only in the social condition for the 1-year-olds as Itakura (2001) suggested. This supports their findings as the experimenter was not the mother and the stimuli were presented further apart from each other. On the other hand, for the 2-year-olds the carryover effect was consistent for both the social and blink conditions. The carryover effect in the blink condition could be explained as a change in interpretation of the stimuli shown by the 2-year-olds. For instance, 2-year-olds might have interpreted the blinking as a referential/symbolic event such as a 'red light' means stop and 'blinking' means caution. There might also be the effect that they attribute the lights' blinking to be the existence of animate agency because the lamps don't turn on by themselves. The response time of both age groups also suggests that the

Table 1 *Percentage of spontaneous pointing in the control, social and blink conditions in phases 1 and 2 for 1- and 2-year-olds. The abbreviations are the same as in Figure 3*

	Control				Social				Blink			
	1ST-R	1ST-L	3RD-R	3RD-L	1ST-P	1ST-NP	3RD-P	3RD-NP	1ST-B	1ST-NB	3RD-B	3RD-NB
1-year olds	12.5 (%)	6.3	12.5	0.0	12.5	4.2	14.6	8.3	0.0	4.2	8.3	6.3
2-year olds	8.3	12.5	0.0	6.3	33.3	6.3	16.7	2.1	4.2	2.1	6.3	12.5

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difference between the two age groups is conceptual and not only quantitative. In general, the 2-year-olds reacted more slowly than the 1-year-olds except in phase 1 of the social condition. For the blink condition, the response was 'automatically' driven by a physical property since they saw that the lamp itself was blinking. But for the social condition the reaction time of 1-year-olds became slower than the 2-year-olds to react. One possible explanation is that it takes more time for 1-year-olds than for 2-year-olds to make a spatial link between the pointing and the lamp. The slower response from the 2-year-olds also confirms our suggestion that 2-year-olds might be reasoning in terms of symbolic interpretation of their environment or the attribution and existence of animate agency that might have driven their interest here. Moreover, 2-year-olds might interpret both the social and the blink conditions as goal directed events (see Subiaul, Lurie, Romansky, Klein, Holmes & Terrace, 2007). If they interpret the blink condition using symbolic rules, animate agency (in this case by either the experimenter or their mother) or goal-directed action, it may explain why the 2-year-olds processed the blink condition in a similar way as the social condition. It is plausible that because of their social reasoning the 2-year-olds showed a carryover effect in both the social and the blink conditions.

Experiment 2: Chimpanzees

In the second experiment we assessed whether chimpanzees respond in the various gaze-following conditions in a fashion that is analogous to that reported for the human children above. From previous studies (e.g. Povinelli & Eddy, 1996) we assumed that chimpanzees will look at the stimulus which is pointed to by E1 or is blinking in phase 1. However, we assumed that they will behave differently in phase 2.

Methods

Subjects

Seven adult chimpanzees ranging in age from 16.4 to 17.3 years served as subjects. The animals have participated in numerous studies involving the interpretation of social cues (such as the direction of eyes, head, body, and pointing), among others (e.g. Povinelli & Eddy, 1996; Barth, Reaux & Povinelli, 2005; see Povinelli, 2000, for a detailed history of each subject).

Apparatus and materials

The same experimental setting (two identical lamps placed on walls, pairs of picture images) as in Experiment 1 were introduced in a testing room at the Cognitive Evolution Group at the New Iberia Research Center, New Iberia (see Figure 1). One wooden bench (30 cm × 43 cm × 32 cm) was used, upon which experimenter 1 (E1) sat. There was a transparent Lexan partition between the subject and E1. A stool (30.5 cm × 30.5 cm × 19.5) in front of E1 was used for the subjects to sit on. There was a small hole in front of the subject's stool. They could reach through this opening to retrieve a food reward. This hole was covered by a transparent barrier during the trial. Four cameras (two wide angle cameras and two focal subject cameras) were used to record the experiment and were shown on a monitor behind the wall. The light fixtures were controlled by a second experimenter (E2) who stayed behind the wall while watching the experiment on a concealed monitor. A third experimenter (E3) controlled the cameras remotely from a separate room outside the testing room. E3 also monitored the time and communicated the timing of the trial sequence to E2 via earphone.

Training. Prior to testing, each subject participated in an undetermined number of four-trial sessions. Subjects were trained to sit on the stool and stay in front of the experimenter for 20 seconds before they received a food reward. This training was necessary for keeping the subjects in the middle of the experimental setting during the experiment. During the training, the apparatus was configured according to Figure 1, except that images were not presented. We defined sitting on the stool and facing the experimenter as the required posture to start participation in the experiment.

Once the subject had entered the test unit at the beginning of each trial, the subject had 1 minute to sit on the stool facing E1. E1 kept a neutral posture. As soon as the subject sat on the stool, E2 turned on both lamps simultaneously and started to measure the time with a stopwatch (no images were presented in the lamps). After 20 seconds, E2 turned off the lamps. E2 lowered the barrier to uncover the hole so E1 could give a food reward to the subject. The trial ended when the subject received the food reward or the subjects failed to sit on the stool before the 20 seconds ended. If the subject did not remain seated on the stool for 20 seconds, they did not receive a food reward, and the trial ended. However, both lamps were kept on until the subject left the test unit. If the subject did not respond within the time limit (1 minute), the trial was re-run immediately. Each session had four identical trials. The subjects were required to remain seated on the stool during all four trials within a session to reach criterion. To advance to Testing, subjects were required to perform correctly for at least one session as a final criterion.

Testing. Testing consisted of eight four-trial sessions; one standard trial and three testing trials with three different conditions identical to Experiment 1 with children: *control*, *blink*, and *social conditions.* Each condition contained phase 1, interval, and phase 2 for presenting the stimulus equivalent with Experiment 1 (see Figure 2). Each testing condition had eight trials in total. There

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were 3 conditions × 8 trials, 24 testing trials in total (plus eight standard trials). The first trial in a session was always a standard trial. Standard trials were administered in the same fashion as the training trials. Only when the subjects performed properly (remained on the stool for 20 seconds) did they proceed to the testing trials. If subjects failed to remain seated for 20 seconds, the standard trial was re-run immediately. If subjects failed again, the session did not continue for that day. The basic testing procedure was the same as for the training sessions. The following three trials included three different condition trials. Conditions were not repeated within sessions. All conditions and the location (left or right) where the experimenter pointed to or the location of the blinking lamp were counterbalanced in a session and across eight sessions.

Procedure

The basic procedure was the same as for Experiment 1. All three conditions consisted of pairs of two identical picture stimuli (see Figure 1) in each lamp on opposite sides of the wall. No pair of pictures was repeated. One experimenter (E1) sat on the wooden bench. E1 faced forward, looking straight ahead to a designated point on the Lexan glass without making eye contact with the subjects while his hands were on his lap (neutral position). The second experimenter (E2) was positioned at the back of the test unit, behind the wall of the experimental setting, to control the response barrier and the shuttle door. Once the subject sat on the stool facing towards E1, E2 turned on both lamps and E3 immediately started to measure the time with a stopwatch for phase 1. Once the lamps had been turned off after phase 2, E1 gave a food reward to the subject irrespective of the response and the trial ended. All timings for the lamp controls were passed on to E2 by E3 via the earphone.

Coding

We analyzed the subjects' behavior based on which lamp they looked at first, based on same coding procedure as in Experiment 1. The main observer (CP) classified the subjects' behavior, according to the categories described above, from the video recordings. To assess inter-observer reliability, an additional coder (SB) watched 50% of all video recordings and rated the subjects' behavior after training in coding. The inter-observer reliability was calculated by means of Cohen's kappa. The agreement and kappa results between the observers were 92.5%, $\kappa = .86$.

Results

First-look behavior

Figure 5 shows the percentage of first-looks in the control, social and blink conditions during phases 1 and 2.

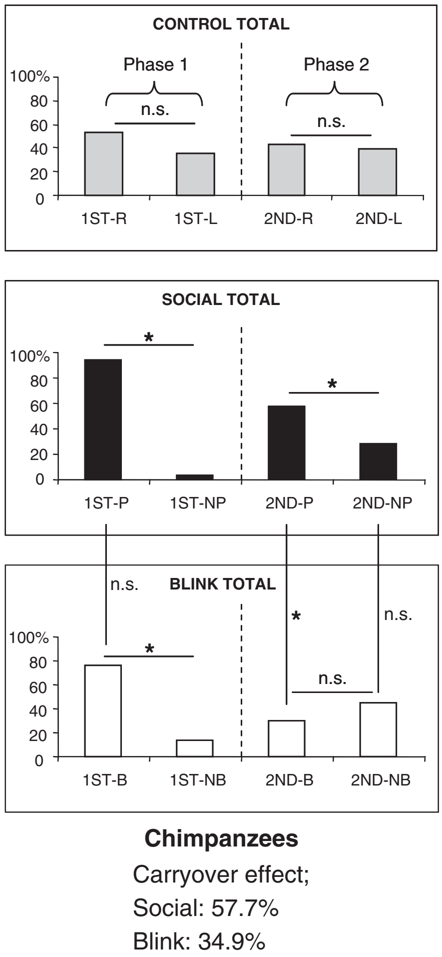

Figure 5 *Average 'looking' responses during phases 1 and 2 for chimpanzees group. '*' mark indicates* $p < .05$.

A Wilcoxon signed ranks test (two-tailed) was conducted with first-look and direction of looking. In the control condition, the first-look for both left and right stimuli was almost the same in phases 1 and 2. There was no significant difference in their first-looks between right and left in either presentation (phase 1, $T(6) = -.95$, $p = .34$; phase 2, $T(6) = -.67$, $p = .50$). This result demonstrates that the subjects did not have a bias to look in one particular direction. In the social condition, there was a significant difference between the subjects' first-look towards the point/pointed-targets and non-targets for the both phases (phase 1, $T(6) = -2.46$, $p = .014$; phase 2, $T(6) = -2.21$, $p < .05$). Frequent looking towards the point-target in phase 1 shows that where subjects looked was affected strongly by the experimenter's pointing. Moreover, this behavioral pattern was carried into the phase 2 ('carryover effect'). In the blink condition, the subjects showed a similar behavioral pattern to the social condition in phase 1. However, this pattern was absent in phase 2 (phase 1, $T(6) = -2.38$, $p = .02$; phase 2, $T(6) = -1.27$, $p = .21$).

Furthermore, we compared subjects' looking behavior between the social and blink conditions. In phase 1, there was no difference between conditions ($T(6) = -1.62$,

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$p = .11$). However, a comparison of the subjects' behavior in phase 2 showed a difference between the blinking stimulus and the pointed stimulus in the phase 1 ($T(6) = -2.21$, $p < .05$). During phase 2, subjects' reaction to the pointed-targets was more robust than their reaction to the blinked-targets. These differences in subjects' behavioral responses were absent for the non-targets for both conditions ($T(6) = -1.73$, $p = .084$).

Carryover effect

We compared the correlation between first-looks in phase 1 and phase 2 to estimate if the looking behavior in phase 1 was carried over to the next presentation, and what kind of stimuli influenced the subjects' behavior. Although chimpanzees did not show the carryover effect significantly in either the social or the blink conditions, the social condition had a stronger effect than the blink condition (Social condition: 57.7%, Spearman's rank correlation (one-tailed); rho = .663, $N = 7$, $p = .052$, Blink condition: 34.9%, rho = .233, $N = 7$, $p = .308$).

Discussion

Like the children, the chimpanzees showed looking responses to the stimulus that blinked or that the experimenter pointed at in phase 1. The looking response continued into phase 2 in the social condition but not in the blink condition. That is, chimpanzees failed to look at the blinked-targets during phase 2. This result resembles the response pattern demonstrated above for 1-year-olds. Specifically, chimpanzees, like 1-year-olds, evidenced a marginal carryover effect (from phase 1 to phase 2) only in the social condition. However, unlike human children, we did not observe any spontaneous communicative actions such as spontaneous pointing or vocalizations towards the lamps and the experimenter.

General discussion

Using a gaze-following paradigm with a subsequent event to measure the subjects' response after their experience of the environment and social interaction, we investigated children's behavior across different age groups and differences in behavior between children and chimpanzees. Human children of 1 and 2 years and chimpanzees showed looking responses to the location that blinked or to the location pointed to by the experimenter during phase 1. All subject groups continued to look to the target location in the social condition. And while 2-year-olds continued to look in the blink condition, 1-year-olds and chimpanzees did not. Moreover, carryover effect analysis showed that only 2-year-olds continued to look at the target stimuli during phase 2 in both the social and blink conditions. One-year-olds and chimpanzees showed this effect only in the social condition. The response time of both age groups also suggests that the difference between the two age groups is conceptual and not only quantitative. In general, the 2-year-olds reacted more slowly than the 1-year-olds except in phase 1 of the social condition.

Moreover, there are also qualitative differences in their spontaneous action between the groups. First, human infants (both 1-year-olds and 2-year-olds) showed some spontaneous communicative signs including spontaneous pointing and vocalizations directed to the lamps and the experimenter. While 2-year-olds pointed or vocalized more than 1-year-olds, chimpanzees made no attempt to communicate with the experimenter either vocally or non-vocally (e.g. banging on the glass, reaching for the target or displaying).

Although we found several qualitative differences in such communicative actions of children and chimpanzees, we also found similarities. Various studies with infant chimpanzees (e.g. Matsuzawa, Tomonaga & Tanaka, 2006; Myowa-Yamakoshi, Tomonaga & Matsuzawa, 2003; Okamoto, Tomonaga, Ishii, Kawai, Tanaka & Matsuzawa, 2002) have shown that chimpanzee's early social cognitive development resembles that of humans; and, in fact, may be homologous. However, comparative studies involving human infants and adult chimpanzees may obfuscate potential homologies in social cognition development. The present study found similarities between human infants and chimpanzees in some measures such as where subjects looked first as well as species differences in the behavioral reactions towards the lamps and the experimenter. For example, both species followed the experimenter's gaze and looked at the stimulus that the experimenter pointed to. Younger children and chimpanzees showed a similar carryover effect pattern in the social condition. However, joint attention episodes in our daily lives contain a more temporal and dynamic dimension as ongoing interaction. Younger children start to show their attempts to continue the interaction by pointing or spontaneous vocalization. On the other hand, we did not observe such reactions from the chimpanzees at all. Thus, although social cues held the subjects' (children's and chimpanzees') attention longer (the carryover effect) and appeared in a similar way on a surface level, there are significant qualitative differences. Our findings also suggest that important facets of joint attention episodes are not only the looking response or looking duration but also whether they treat the social event as an ongoing interaction with others. Some previous studies also reported differences in the early development of infant chimpanzees. Okamoto, Tanaka and Tomonaga (2004, see also Tomonaga, Tanaka, Matsuzawa, Myowa-Yamakoshi, Kosugi, Mizuno, Okamoto, Yamaguchi & Bard, 2004) reported that after an infant chimpanzee followed the experimenter's gaze and pointed towards attractive stimuli, he did not try to look at the experimenter and the stimuli alternatively, sharing attention. However, even if human children had some prematurity in their early stage of social cognition which looks homologous to that of

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chimpanzees, they already showed a germination of the fully-fledged social cognitive skill such as producing communicative actions, and show differences in the later stage of their development.

Among children, spontaneous pointing was most common in the social condition. Children typically pointed to the lamp that E had pointed to. Children typically intermixed pointing to the lamps and looking back at the experimenter in an alternating fashion; joint attention in a triad relationship (attempt to share attention). Two-years-olds, in particular, pointed more during phase 1. Children's spontaneous pointing might be triggered by seeing the experimenter's pointing as a communicative signal. Previous studies that have extensively investigated children's pointing production report that infants' declarative pointing emerges at around 1 year of age with regard to its underlying socio-cognitive understanding and motive to share experiences with others (e.g. Liszkowski, Carpenter & Tomasello, 2007). Our observation of spontaneous pointing from both 1- and 2-year-olds supports these results. However, the pointing reactions in our study might also represent a familiar motor imitation response where children, failing to understand why the experimenter has pointed to a given lamp, copy the model's actions automatically. Certainly, there is evidence suggesting that human children are hyper-imitative at different stages in development and in different contexts, particularly when they don't know what is going on in their environment (e.g. Horner & Whiten, 2005). Conversely, children might have pointed intentionally as a means of initiating a joint referencing event. In any case, our result suggests that seeing the experimenter's pointing action triggered the spontaneous pointing reactions by children. Since our study did not intend to investigate directly eliciting pointing actions, future research should include control conditions such as the experimenter changing emotional expression towards the stimuli or making eye-contact at the beginning of a trial.

The social condition also triggered vocal reactions from the children. Their vocalizations were often accompanied with pointing at the lamps and looking at the experimenter alternately. This observation clearly supports the idea that the children (especially older children) took the social condition joint attention episodes as an ongoing social event. As such, they tried to respond to the experimenter by pointing to the same object or saying something as part of a natural communicative interaction. This might answer our earlier question about why social cues keep younger children's attention longer (carryover effect) than a salient object does. Additionally, when the children pointed after/with following the experimenter's cues, their pointing often alternated in direction. For instance, they pointed to the stimulus pointed at by the experimenter, and then pointed to the other stimulus and checked back with the experimenter, and then again pointed to the stimulus that had been pointed to. These sequential actions imply children's attempt to understand the communicative intent of the model and resolve conflicting interpretations of the communicative event.

We also found that older infants keep their attention longer even in the physically salient blinking condition, unlike younger infants and chimpanzees (and also 11-months-olds in Itakura's study). For older infants, both social referentially highlighted objects and physical saliently highlighted objects had an equivalent (or similar) impact on their understanding of the environment. Although less frequent, older infants did show communicative actions towards the lamps and the experimenter, especially in phase 2 in which the lamp was not blinking. Why did they produce such actions even though there was no pointing model in the blink condition? We assume that it was because there were other people present in the setting, as we have a tendency to reason about our environment especially when we see some unusual event happening (e.g. Subiaul *et al*., 2007). If someone is present we like to share the event and try to seek information from others. Maybe if there had been no one in the test setting, they might not have produced any communicative actions. Thus, their communicative actions were produced in an attempt to understand their environment and consider others as an information source (and also as psychological agents) when sharing the same event (or they might request sharing the event). So there might be two tightly linked phases for such joint 'conceptual' attention. The first one is the phase of automatic/reflexive gaze following (or attraction to salience) and the next one is the phase of comprehension (understanding the contextual and conceptual meaning of the environment). We very often consider 'fully-fledged' joint attention as a triadic relationship with child, adults and objects or an event (e.g. Tomasello, 1999). Do we do this just because we feel satisfaction in following gaze and at the same time realizing that the other individual is a psychological agent and is also looking at the same thing? We might also, as a process of social referencing, try to check whether the event itself and emotional perception about it is equivalent or similar to others' experience. So motivation is not only sharing attention with others but also sharing conceptual and contextual aspects of the environment (such as possible or negative events). Older subjects 'actively' interact with others and send a communicative signal such as spontaneous pointing or vocalization, even though the experimenter and their mothers are not interactive (they quietly sat there with the infants and were not looking at the blinking lamps). Thus, children are no longer only receivers of communicative signals from others; rather, they start to become senders of communicative signal to others, and they become initiators of communication.

In sum, our study demonstrated differences between chimpanzees and 2-year-olds, and between 1- and 2-year-old children during ongoing joint attention episodes. In particular, 1-year-olds' and chimpanzees' looking data

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showed some similarity on the surface but, upon closer inspection such as children's spontaneous communicative actions, there are significant differences as well. In the future, we should conduct more detailed comparative examinations of the development of joint attention behaviors as well as their underlying mechanisms. In addition, such studies should be designed to investigate the development of spontaneous communicative actions. Future research will provide a clearer idea of visual communication including joint attention and the understanding of social-cognitive abilities in primates.

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