Tracing the development of primate social attention: Where do human and nonhuman paths diverge?

Katherine Wagner
University of Chicago
Chicago, IL 60637
keq.wagner@gmail.com

Throughout infancy, chimpanzees and humans demonstrate parallels in the development of visual attention capabilities, as a channel of information–collection and a communicative signal. However this shared path appears to diverge at the end of the first year, when humans begin to demonstrate triadic interactions, in which each partner is aware of a common attentional focus, a "shared attention". Conversely, neither shared attention nor resulting triadic interactions have been consistently reported for chimpanzees either incidentally or in studies that explicitly seek to capture or elicit these interactions (Tomonaga, et al., 2004).

Behavioral indications of triadic engagement capabilities in humans include object showing behaviors, pointing and looking back to the dyadic partner, highlighting the understanding of a shared attention target. Although chimpanzees have not been observed to engage in these types of interactions, infants' use of novel objects seems to be affected by maternal manipulations of the object (Tomonaga, 2004). Such interactions may demonstrate a "triadic precursor": a rich object-actor dyadic interaction stretched to incorporate an animate partner at the interaction periphery. Given the observation in apes of many surface-level abilities thought to enable triadic engagement (e.g. attention to face, gaze-following abilities) (Kaminski, et al, 2004), this protostate termination of attention development is of uncertain etiology.

In exploring this species difference, valuable attention is increasingly being directed to the mother-infant dyad, as the context in which human triadic interactions first emerge. The frequency and behavioral sequence of mother-infant mutual gaze is similar in humans and chimpanzees, including an inverse relation between gaze and tactile contact (Tomonaga, 2004). However, Bard, et al. (2005) found that the duration of these mutual gaze sessions was shorter in chimpanzees compared to humans. Such differences in gaze duration and social attention scaffolds may be critical in developing a synchrony in gaze patterns. This process, in turn, may provide early and necessary practice in matching gaze direction, pairing gaze with a socio-affective context and expanding the plane of dyadic mutual gaze dyad to include an external object in a "referential triangle" (Naber, et al., 2007).

Teuscher & Triesch (2007) found that a computational human infant model demonstrated the most rapid acquisition of gaze following when paired with a caregiver model that engaged in mutual gaze both before and following a saccade to an object. The longer duration mutual gaze sessions observed in humans may operate similarly, providing a more robust guide with which an infant may predict subsequent, object-directed caregiver gaze. In humans, this ability may develop into an especially rich form of attention, triadic interaction, as a result of such social – and socially-guided - input into evolutionarily-shaped cognitive mechanisms that support high level hierarchical actor-object relations (Saxe, 2006).

A similar epigenetic robotics approach may be critical in examining the fine-scale and ephemeral processes of shared attention that, in behavioral assessments, may be subject to sweeping biological variability (i.e. maternal skill, rearing history, etc.) and complex social input (Nagai, et al., 2003). This perspective may be particularly valuable in examining species differences relating to a limited-scope phenomenon, such as mutual gaze, which requires only relatively simple pre-existing mechanism (e.g. attention to face, eye contact detection) (Breazeal & Scassellati, 2000 ; Butterworth & Jarrett, 1991) and avoids embodiment-related issues regarding emerging locomotor capabilities (Lindblom & Ziemke, 2006). For example, simple "human-" and "chimpanzee-" infant robots, each constructed with a feature- or perceptual salience-based recognition of mutual gaze may be exposed to long- and short-duration mutual gaze sessions (but at a matching frequency); over numerous repetitions of such bouts the models may be assessed for differences in gaze synchrony (i.e. time to make contact, duration of successful contact, etc.) with a caretaker (Nagai, et al., 2006). If differences in such measures of synchrony are detected, then the observed differences in mutual gaze may 1) indicate a point of divergence in human and nonhuman social attention development and 2) offer a resolved focus for further examinations of the developmental course of sophisticated forms of social attention. The more experienced ("toddler") versions of these models could be employed in more sophisticated tasks of gaze following to trace out the differential attention development in the "human" and "chimpanzee" (Hoffman, et al., 2006) - perhaps requiring a layering on to these models representations of appropriate physical and locomotor development (Lindblom & Ziemke, 2006).

While certainly informing the understanding of attention development, the identification of such early precursor behaviors as mutual gaze in experimental robotic systems may also be of special concern in the pursuit of an epigenetic representation of human social cognition in general. The experience and expression of these early forms may be critical both in establishing an appropriate developmental course that parallels human ontogeny and as a metric along which to compare advanced attention manifestations. The integration of a cross-species perspective in this work may also provide the field of epigenetic robotics with necessary micro-developmental details that ultimately delineate an appropriate course of human development - holding significant implications for application in further empirical work and Human-Robot Interaction.

Looking forward with an expanded scope, the sophistication - and our understanding - of these models may be best enriched by complementary, cross-species examinations of the cognitive-behavioral, physiological and neuroanatomical manifestations of social attention at the macro level.

From a distributed cognitive approach, cooperation, in which each individual monitors both a dyadic partner and a third object (or specific quality of an object) (Kaplan & Hafner, 2006), may offer a possible ecological stage for further behavioral and physiological analyses of triadic interaction capabilities in nonhumans (Melis, et al., 2006). As a potential starting point, a cooperation paradigm might incorporate a turn-taking “game”, wherein the subject and the partner must both monitor each other’s actions on a “game board” to watch for and take a responsive and time-sensitive specific action, to receive a reward. In this case, evidence for or against a shared attention capability would be indicated not in the game itself, but in the attention-getting gestures (or lack thereof) employed by the subject to regain the attention of the partner, once intentionally distracted from the task by the experimenter.

While this “game”, played out among a chimpanzee and/or human dyad remains vulnerable to many methodological challenges raised in other empirical examinations of social attention (Hare, et al., 2000), such a paradigm would also offer opportunities for replication with epigenetic robotics. This nexus of empirical approaches would permit, on one hand, an increasingly fine-tuning of constructed models and model inputs and, on the other, a platform on which to better examine the precise cognitive processes that underlie and differentiate humans in the corpus of social attention capabilities.

References

Bard, K., Myowa-Yamakoshi, M., Tomonaga, M., Tanaka, M., Costall, A., & Matsuzawa, T. (2005). Group differences in the mutual gaze of chimpanzees. *Developmental Psychology, 41,* 616-624.

Breazeal, C. & Scassellati, B. (2000). Infant-like social interactions between a robot and a human caregiver. *Adaptive Behavior,8,* 49-74.

Butterworth, G. & Jarrett, N. (1991). What minds have in common is space. *British Journal of Developmental Psychology, 9,* 55-72.

Hare, B., Call, J., Agnetta, B., & Tomasello, M. (2000). Chimpanzees know what conspecifics do and do not see. *Animal Behaviour, 59,* 771-786.

Hoffman, M. W. Grimes, D.B., Shon, A.P., & Rao, R.P.N. (2006). A probabilistic model of gaze imitation and shared attention. *Neural Networks, 19,* 299-310.

Kaminski, J., Call, J., & Tomasello, M. (2004). Body orientation and face orientation: two factors controlling apes’ begging behavior from humans. *Animal Cognition, 7,* 216-223.

Kaplan, F. & Hafner, V.V. (2006). The challenges of joint attention. *Interaction Studies, 7,* 135-169.

Lindblom, J. & Ziemke, T. (2006). The social body in motion: cognitive development in infants and androids. *Connection Science, 18,* 333-346.

Melis, A., Hare, B., & Tomasello, M. (2006). Engineering cooperation in chimpanzees: social tolerance constrains cooperation. *Animal Behaviour, 72,* 275-286.

Naber, F., Swinkels, S., Buitelaar, J., & Dietz, C. (2007). Joint attention in toddlers with autism. *Journal of Abnormal Child Psychology, 35,* 899-911.

Nagai, Y., Hosoda, K, Morita, A., & Asada, M. (2003). A constructive model for the development of joint attention. *Connection Science, 15,* 211-229.

Nagai, Y., Asada, M., & Hosoda, K. (2006). Learning for joint attention helped by functional development. *Advanced Robotics, 20,* 1165-1181.

Saxe, R. (2006) Uniquely human social cognition. *Current Opinion in Neurobiology, 16,* 235-239.

Teuscher, C. & Triesch, J. (2007). To each his own: The caregiver’s role in a computational model of gaze following. *Neurocomputing, 70,* 2166-2180.