Pointing gesture in a bird—merely instrumental or a cognitively complex behavior?

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Abstract Gestures, particularly pointing, are regarded as important pre-speech acts. Intentional and referential pointing has been shown previously in humans and apes but not in songbirds, although some avian species show cognitive abilities rivaling those of apes, and their brain structures and functions show putative preconditions for referential gestural signaling (i.e. mirror neurons, links of vocal learning nuclei to discrete brain areas active during limb and body movements). The results reported are based on trials testing predator detection and responses to a taxidermic model of a wedge-tailed eagle by Australian magpies Gymnorhina tibicen. Magpies were subjected to three conditions of finding this model in their territory (open, sheltered and hidden). In the sheltered and hidden conditions, the discoverer simultaneously engaged in alarm calls and beak pointing, a behavior that has not been described previously. Other group members at once assembled and, after watching the first bird, adopted the same posture by pointing to the location of the intruder. The question is whether beak and body movements orienting towards important stimuli or events are instances of arousal, imitation or intentional communication. The latter presupposes that onlookers interpret the signal and respond by altering their own behavior appropriate to the original stimulus and not merely by imitating the first signaler. Evidence presented here indicates that the act of pointing may well be a complex cognitive behavior, i.e., an intentional and referential signal, showing that pointing is not limited to having hands and arms [Current Zoology 57 (4): 453–467, 2011].

Keywords Pointing, Birds, Cognition, Communication, Intentional signaling

This paper presents results of the behavior of pointing in an avian species and attempts to link these findings to debates on the relative theoretical importance of pointing in human and other primates. Much research on gestures (by limbs, among them pointing, body postures and direction of the eyes) is driven by a desire to understand human cognitive and speech development or, more broadly, to seek in nonhuman primates evidence for precursors to the evolution of human language. Bird behavior does not fit easily into this debate despite the fact that songbirds specifically share with humans (but not other primates) the ability for vocal learning. A number of papers have identified converging mechanisms in birdsong and human speech (Jarvis, 2004; Bolhuis et al., 2010) and, as far as vocal communication is concerned, humans and songbirds are at the apex of that ability (Zeigler and Marler, 2008). Gestures have featured in primate research while cognition in birds had largely focused on problem-solving, memory tasks (Clayton and Dickinson, 1998) and tool use (Clayton and Jolliffe, 1996; Hunt, 1996). This paper addresses the gesture of pointing in an avian species, the Australian magpie Gymnorhina tibicen.

Pointing and its relationship to human language development and cognition

For an individual to be able to perform an act of pointing, it had been thought, limbs and even fingers are required. Human pointing may involve the entire length of the arm and the hand, shaping it so that one finger specifically points in the direction of the desired/indicated object. Infants make pointing gestures spontaneously from an early age (Liszkowski et al., 2004; Petitto, 1988). Pointing has often been singled out as a key behavior for understanding development of language and a theory of mind. Indeed, Butterworth (2003) called pointing “the royal road to language for babies”. Others have argued that the act of pointing is a complex cultural domain “where language, culture, and cognition meet” (Kita, 2003), and yet others have associated declarative pointing with theory of mind (Camaioni et al., 2004).
Research interest in pointing is thus related to understanding how human language evolved. This has led to investigating pre-linguistic and language ability in apes. Although it was shown that great apes have no facility to produce human speech sounds despite years of attempts of teaching chimpanzees to speak (Gardner and Gardner, 1971), they do possess a complex gestural repertoire that could be employed to perform certain pre-speech acts (chimpanzees: Goodall, 1986; Krause and Fouts, 1997, Hopkins and Leavens, 1998; bonobos: Savage-Rumbaugh, 1986, Véa and Sabater-Pi, 1998; orangutans: Kaplan and Rogers, 2000). Apart from instrumental pointing, which is said to be neither intentional nor referential and thus not cognitively complex, some researchers dismissed the existence of pointing in apes altogether (Povinelli et al., 2003; Tomasello, 2006).

Against this skepticism, studies introducing sign language to apes (Gardner, Gardner, van Cantfort 1989), have shown that all apes, to varying degrees of success, are capable of displaying an understanding of words, objects, commands and even numeracy (chimpanzees: Boysen and Bernston, 1989; bonobos: Savage-Rumbaugh, 1984; gorillas: Patterson, 1978; orangutans: Miles, 1990) and this abstract ability, dealing with symbolic representation of language and thus complex cognitive processes, has led to more detailed investigations both of behavior and of the structure and function of the primate brain (Maestripieri, 1999).

There is still much debate as to lateraled hand use in primates generally (Kruper et al., 1966; Lockard, 1984; McGrew and Marchant, 1997; Rogers and Kaplan, 1996; Spinozzi et al., 1998, Vauclair et al., 2005), which hemisphere is active and whether a case can be made of the interrelationship between vocal, motor and cognitive responses. Hopkins et al. (2007b) and Taglialatella (2007) have collected an extensive research record on right-handedness and gestures in chimpanzees. Right-handness has been found in chimpanzees and this indicates use of the left hemisphere in areas associated with and homologous to human brain areas of speech (Hopkins and Cantero, 2003; Hopkins et al., 2005; Hopkins et al., 2007a).

In birds, extensive records exist that they are laterialized in brain functions and thus process certain events and sensory inputs in specific hemispheres (Güntürkün, 2002; McKenzie et al., 1998; Rogers, 2008; Vallortigara et al., 2001), although evidence of such laterization for non-domesticated avian species is still sparse. Indeed, so far, to my knowledge, there have been only two studies specifically testing lateralized viewing of birds in the wild, one on the black-winged stilt (Ventolini et al., 2005) and another fieldwork emanating from our laboratory on Australian magpies (Koboroff et al., 2008). In stilts, this was related to predatory and sexual behavior and in magpies to exposure to and inspection of a predator.

Some researchers also believe that pointing in great apes was merely a human entrained characteristic and does not occur in the wild (Zimmermann et al., 2009). This has been found to be incorrect. Pointing is not only understood by great apes when seen performed by humans but is used as a gesture to conspecifics, at different levels of complexity (Call and Tomasello, 2007; Goodall, 1986). Great apes and even some monkey species may use gestures intentionally and referentially in the presence of an onlooker provided the individual has that onlooker’s attention (Brinck, 2001; chimpanzees: Leavens et al., 1996, Leavens and Hopkins, 1998; Leavens et al., 2004, 2005; Pika and Mitani, 2006; Russell et al., 1997; orangutans: Bard, 1992; Cartmill and Byrne, 2007, 2010; capuchins: Hattori et al., 2007).

‘Pointing’, including eye-gaze following (more later), has thus been of singular interest because of the perceived causal connection between developments of gestures in social contexts in apes and humans and the evolution of human language, referred to as the motor theory of language acquisition. This theory has had a very long research history (Washburn, 1919; Corballis, 2002), although it has certainly had its critics (Gallantucci et al., 2006; Hickok, 2009), not least of which concerned the debate about the suggested existence, proven or not, of a mirror neuron system in humans. A number of neuro-imaging studies have argued that a mirror neuron system (MNS) exists in humans and that homologous areas in the human brain are similarly activated when observing and executing movements (see Morin and Grèzes 2008 for their review of these studies). However, Kilner et al. (2009) and others have wondered as to whether any of the human neuro-imaging studies constitute conclusive evidence for mirror neurons in humans (Dinstein et al., 2008). Regardless of the controversies, these discoveries and claims lend weight to the theory that human language evolved from gestures (Corballis, 2002; Kendon, 1980).

Neuroscientists have approached the problem of finding equivalents of gestural behavior in other primates by looking for areas in the brain that might be homologues of the areas in the left hemisphere of the human brain associated both with speech production (Broca’s area, Broca, 1865) and language comprehen-
sion (Wernicke’s area, Wernicke, 1874). Such equivalents have been found (Cantalupo and Hopkins, 2001; Gannon et al., 1998, Gil-da-Costa et al., 2006) as well as a very exciting new finding of so-called mirror neurons. The discovery by a research team in Parma of motor neurons in the prefrontal area F5 in the macaque brain, *Macaca nemestrina* (Di Pellegrino et al., 1992; Rizzolatti et al., 2001; Umilta et al., 2001) and subsequently in the rostral inferior parietal lobule, area PF (Gallese et al., 2002, Fogassi et al., 2005), showed that certain neurons respond both when the macaques made active movements and when they merely observed others making such movements. Neurons for eye gaze and eye-gaze following have also been identified in the brain of humans and other primates (Kamphuis et al., 2009). In humans, it has been shown that the superior temporal sulcus (STS) is specifically activated when subjects actively follow the eye gaze of others. Similarly, an analogous region in a primate’s middle STS has been identified that also responds to gaze following (Kamphuis et al., 2009). These findings seemed to provide the long-awaited bridge between motor action (such as pointing) and its translation into meaning and understanding - as well as providing a vehicle for explaining how language and speech perception might have evolved via motor action in gestures and pointing, involving mirror neurons, eventually to language.

**Pointing and its relationship to social cognition in animals**

The impression that such research on human and nonhuman primates gives, however, is misleading because it still infers evolutionary uniqueness of pointing in the primate line, with its link to (human) symbolic communication and theory of mind. Indeed, for some time the entire debate on the cognitive domain in animals had perhaps been presumed to be too much of a prerogative of primates (Rogers and Kaplan, 2004). Quadrapedal animals, such as dogs and horses, or animals without arms, such as dolphins, seemed to be at first precluded from pointing until casual observation made it quite clear that this is not so. Domestic dogs and guide-dogs (Ittyerah and Gaunet, 2009; Lakatos et al., 2009), wolves (Viranyi et al., 2008), horses (Maros et al., 2008) and dolphins (Xitco et al., 2004) can be trained to understand the meaning of a pointing gesture by humans whatever the context may have been. Head-turning or whole body turning and even eye gaze and eye-gaze following (Anderson et al., 2007; Hattori et al., 2007; Kamphius et al., 2009; Kaplan and Rogers, 2002) can replace pointing. Indeed, there is a growing literature on gaze following, showing that this ability may be very widespread having been found in lemurs (Ruiz et al., 2010) and Japanese macaques (Kumashiro et al., 2008), as well as in goats (Kaminski et al., 2001), tortoises (Wilkinson et al., 2010) and birds (Bungyar et al., 2004; Loretto et al., 2010).

Apart from work on viewing in chicken by Marian Dawkins (1995, 2002) and by an Italian research team (Salva et al., 2007), relatively few avian species have ever been tested for their ability to understand pointing or eye-gaze following (when directed at an object by another party), let alone their importance in various contexts. Singular projects have been conducted concerning African gray parrots (Giret et al., 2009), bee-eaters (Watre et al., 2002), bobwhite quails (Jaime et al., 2009), Northern bald ibises *Geronticus eremita*, jackdaws (Van Bayern and Emery, 2009), starlings (Carter et al., 2008) and ravens (Schloegl et al., 2008), showing that these species are capable of eye-gaze following and of seeing what others see, as had been found in primates.

Hand gestures or eye gaze may be used to attract the attention of another to look in the same direction and thus, in principle, achieve the same communicative triad between self/other and object, as also occurs in begging for food (Kaplan and Rogers, 2002; Anderson et al., 2007). Indeed, so widespread are the examples of gaze following and attention to others now that the argument is shifting, in gaze following at least, from seeing this as evidence of complex cognition to being a mechanism for basic survival. Wilkinson et al. (2010), for instance, suggest, on finding gaze following in a tortoise *Geochelone carbonaria*, that gaze following could have evolved in early vertebrates, or may result from a general ability to learn. Put simply, as Jaime et al. (2009), have done so succinctly, gaze following of another individual offers many opportunities for a social animal: to detect predators, to locate food sources, and to witness important social interactions (Emery, 2000; Zuberbühler, 2008). Magpies are social animals and it is hypothesized in this paper that magpies might be able to follow gaze and initiate and respond to pointing in addition to their substantial vocal repertoire (Kaplan et al., 2009).

It would be easy to infer from the human and nonhuman primate literature that pointing requires a mammalian brain, i.e., a neocortex able to form representations of motor actions, particularly of the limbs and, perhaps also of eye gaze. Birds do not have a neocortex (although they have pallial regions thought to be equivalent to a neocortex, Jarvis and Consortium, 2005).
and they do not have arms. Moreover, the beak is fixed and birds have relatively little eye movement (McFadden, 1993; Martin, 1986, 2007). However, species with the ability for vocal learning, as identified in humans, songbirds and some cetaceans, might also have developed ways of signaling and reading signals related to gestures and movement. Indeed, the existence of vocal referential signaling in birds has already been explored and experimentally verified in birds (Evans, 1997) but so far not been extended to gestures.

In order to test this latter hypothesis Australian magpies were tested in the field. The results reported here were part of a larger study on anti-predator strategies and referential signaling in Australian magpies. The method is summarized here as much has been described elsewhere (Kaplan, 2002; Kaplan et al., 2009; Korboff et al., 2008). The magpie is one of the foremost songbirds of Australia (Kaplan, 2006) and, in several subspecies, can be found throughout the Australian continent. Male and females sing (Deng et al., 2001), and use a sizeable number of alarm calls (Jurisevic and Sanderson, 1994), which suggests that these vocalizations might have specific communicative functions (Kaplan, 2002, 2008). Magpies are territorial and play an important role in any predator alerts in their territory, also warning avian heterospecifics (Kaplan, 2005). Finally, one of their most dominant anti-predator strategies is to mob vocally while executing swooping flights (Korboff, 2009). In collaboration with all other adult conspecifics in their territory, magpies orchestrate well-executed attacks, which may involve direct contact preferably to the back of the neck of a predator (Kaplan et al., 2009). They are exclusively social: either living in bachelor flocks (3–5 years or more) or in family groups ranging from permanent pairs with seasonal offspring to larger groups, with offspring staying some years in, or not dispersing from, the natal territory (Veitman and Carrick, 1990). Some magpie groups use cooperative ways of raising young, while all magpies, without fail, cooperate in the defense of territory and in attempts to drive out a predator or conspecific intruder. These factors combined should make it all the more likely that they would also find ways of communicating about unusual but important events that would safeguard their territory, if not their own survival.

1 Materials and Method

1.1 An important preceding observation determining the method

The discovery of a behavior in magpies that appeared very similar to pointing was first made as an anecdotal observation during ongoing study on vocal behavior and aspects of anti-predator behavior in experiments involving, among others, the presentation of a taxidermic model of a locally extant aerial raptor, the wedge-tailed eagle *Aquila audax* (Kaplan et al., 2009). To verify the observation, magpie groups were tested formally using some of the same research sites and some of the same magpie families as in the previous study. All experiments were conducted on the New England Tableland, near Armidale, New South Wales, Australia (30°32′S, 148°29′E).

The incident involved a live but injured wedge-tailed eagle (broken wing) that was temporarily placed in a wire-netted coral (no roof/no wiring on top) under a tree (abbreviated version Rogers and Kaplan, 2005). A magpie spotted the eagle and then performed a series of alarm calls (see Kaplan et al., 2009) until all other magpies within the territory were present. As each magpie arrived, the initiator of the calls lent forward so far, almost falling off the perch, that the angle of the body was nearly 45° below its normal resting position, with the body forming a straight line with beak facing the eagle (see Fig. 1).

The pointing gesture was exaggerated and performed in relation to incoming magpies and maintained for most of the time it took all magpies to assemble in the same spot. Each arriving magpie landed on a branch near the incessantly alarm-calling magpie A, watched A and then turned its head until the hidden eagle was spotted, then it too adopted the same posture as A and also began calling. Six magpies flew in (the entire family) and eventually all were positioned in a semi-circle around the predator (see later). After 20 minutes, most magpies had departed except one senior male staying behind as a sentinel. He flew off only after the eagle had been moved into a covered aviary. That was an hour after the event.

1.2 Design and rationale for the experiment on pointing

To recreate the event, an experiment was conducted using three of six of our established rural research sites just outside Armidale. The three sites were 1) Arding, 2) Uralla and 3) Saumarez. Sites were separated by at least 10 km to minimize relatedness of individuals. Human population is sparse and farmland is interspersed with open woodlands. The sites were selected according to the following criteria: 1) Suitable environment to recreate natural events (rural): our results of eliciting alarm calls in response to seeing a model of a wedge-tailed
eagle had shown that responses were significantly higher in rural areas where two pairs of eagles actually lived at the time and also nested (Kaplan et al., 2009). 2) Group membership of at least 5 to ascertain whether direction of pointing was adopted by other group members. 3) Topography of the location had to be such that it offered roosting spots for all incoming magpies, low enough foliage to hide an eagle underneath it and, finally, a structure with different angles away from the stimulus to further reveal whether ‘pointing’, if it existed, was an intentional body gesture or merely an indication of the direction of the landing spot or an imitation of the preceding magpie’s posture.

Out of six rural groups used in our previous studies, three qualified as fulfilling all the required conditions. The number may appear low but most territories of magpies contain large open areas with few interspersed trees and barely any understory. Rural territories of magpies also tend to be very large (10–100 acres) and finding a group can be difficult. The three groups selected had a total of 7 birds in two groups and 6 birds in the third (total of 20 birds).

Magpies were tested under three conditions 1) the eagle was placed as close to the centre of the group’s territory as possible to avoid debates about the relative significance of intrusions at edge versus centre of a territory (Brown et al., 1993). For this trial, the stimulus was placed on the ground in the open and the experimenter retreated to a distance of at least 20 m and hid behind any available structure, from where behavior was recorded. Recording during presentation of the stimulus commenced at a magpie’s first vocalization or first approach to the stimulus (to within 10 m of the stimulus). Behavior was recorded for 5 minutes prior to testing, during testing (5 min) and 5 minutes post testing (note that the magpies did not move away when the experimenter took the stimulus away). 2) In the second condition, the taxidermic eagle model was placed under a shrub or tree, replicating the conditions of the original observation. The landscape was largely open grassland. The same testing framework was otherwise used. 3) In the third condition, the eagle model was again placed under foliage but was hidden more than in the second condition in a landscape of woodland. In addition, a perching spot off the ground had to be a fence or a structure (two benches) put at an approximately 120° angle to each other so that some of the perching magpies would have to turn their bodies towards the eagle if they were ‘pointing’ rather than just looking.

As magpies are extremely vigilant, it would have been unlikely, if not impossible, to try and walk around carrying an eagle and then hide an object as large as an eagle within their territory without being detected. In order to make this test convincing, it was necessary to place the taxidermic model into testing position under cover of darkness a night before testing, cover it with a rainproof inconspicuous olive green cloth (with nylon line attached) and return just before dawn the next day, take up a hiding position, waiting for magpies to be in visible range and then pull on the line to remove the cover from some distance.

The birds were tested in three separate trials (1 trial for each condition) and these were repeated the following year. Hence each group received 6 trials and each
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bird was scored individually. Presentations of the stimuli were made in 2003 and 2004 between the months of Sept (spring) and early December (summer), including two breeding seasons (locally largely between July–October) and overlapping with the breeding seasons of wedge-tailed eagles (locally between July and September). The time was chosen because of the presumed greater reactivity of magpies during the breeding season. For recording vocalizations a Tascam DAT recorder (model DA-P1) and a uni-directional Sennheiser microphone (model ME66+K6P) were used, mounted on a tripod in the direction of the stimulus. Vocalizations were scored, but only the first minute of the five minute testing period was recorded, since a large library of alarm calls elicited during similar experiments was already in hand. 125 alarm call sequences were analyzed using Cornell University Ornithology Laboratory software programs (Raven 1.2.1).

1.3 Behavior scored
Any small movements, turning of the head such as viewing conspecifics or looking around was not measured and considered too inaccurate because of distance of observer. However, any obvious movements of the head or body were scored. The presence and behavior of each incoming magpie were recorded. Exposure to the stimulus was terminated 5 minutes post discovery by the first magpie.

1.3.1 Body angle for pointing
In normal body posture the magpie’s head is held up well above the shoulders. For an event to count as beak pointing, a) body and beak had to show a downward angle, a posture more angled (30–45° difference) than is normal for feeding (Fig. 1); b) body and beak had to form a straight line from beak to tail feathers but angled down from normal horizontal line between head and shoulder; and c) the beak had to be directed at the taxidermic model of the eagle. A single score was given if a bird was observed holding this position for 5 continual seconds and each bird was scored individually. A new score was given when a bird resumed the posture after having changed body posture, such as sitting up or turning around or moving the head.

1.3.2 Head upright and body erect was scored as vigilance behavior (Fig. 2 A) Exaggerated movement of the head from side to side usually with outstretched neck (Fig.2 B), rarely seen in magpies, similar to an Indian dancer (shoulders not moving but head only). It was scored because it suggests intense looking, as if trying to find something.

Flight intention movement: raised body and raised wings but staying in position on perch, indicating several things: the vocal signal had been recognized but eagle had not been detected and the bird became insecure and responded by flight readiness. Or, the bird had not understood what the purpose of the gathering was and remained there only for social reasons (i.e. when the others stayed).

1.3.3 Viewing Looking up after landing on a perch. Since the already present magpies used a special set of calls for aerial predators (Kaplan et al., 2009), looking up (head and beak raised, facing up) would indicate that the bird had followed the vocal rather than the visual

Fig. 2 Other body postures observed in response to beakpointing and alarm calling by conspecifics
A. Vigilance posture: stretched body and extended neck, beak slightly elevated. B. Exaggerated head movement from side to side (shoulders still). C. Flight intention movement (stretched body, raised wings) – looking up is not necessarily part of the flight intention movement but was in this study.
signal of pointing. Head tilts (left-eye viewing) are typical ways of looking up (Rogers and Kaplan 2005) but this could not always be ascertained from the distance of 20 meters.

Obvious eye-gaze following involving a postural or head turn or both: Looking first at the alarm calling and pointing magpie, then in the direction of the eagle. Each such event was scored separately, even when several such looking events were executed by the same bird.

2 Results

2.1 Pointing

Bouts of pointing are summarized as group scores in Table 1. As can be seen, no single incident of pointing was recorded in Condition 1, the most naturalistic setting. However, Conditions 2 and 3 (hiding the eagle under some foliage), yielded behavior of pointing as defined in the method section (1.3.1). There were no significant group differences in response to presentations in Conditions 2 and 3, but pointing was substantially higher in Condition 3, indeed, it more than doubled from Condition 2 to 3, and was even tripled for group 3. In Condition 2, a mean of 11 bouts of pointing (of all 3 groups in all 3 conditions) were scored and in Condition 3, a total mean score of 24 events of pointing were recorded (a score was given only when the behavior was at least of 5 sec duration). Importantly, most incidents of pointing occurred in the first minute after the presentation of the eagle. As Fig. 3 indicates, incidents of pointing were highest at the beginning of exposure to the eagle model, dropped off sharply by the second minute of the test and were almost down to zero in the fourth minute of testing. This pattern was similar in Conditions 2 and 3 but note the different scales on the Y-axis between Conditions 2 and 3, reaching just 7 pointing events in the first minute in Condition 2, but well over 20 in Condition 3, also in the first minute. In Condition 3, to reiterate, the eagle model was difficult to spot in a wooded area and of all conditions, this was the one in which the eagle was best hidden and least visible from a distance. Fig.4 provides arrival time of each bird versus pointing rate. As can be seen, the first arriving birds do most of the pointing while the last two birds in all groups did not engage in any pointing. In other words, pointing rate is not maintained at a similar rate

| Condition | 1 | 2 | 3 |
|-----------|---|---|---|
| Groups    | 1 | 0 | 10 | 21 |
|           | 2 | 0 | 13 | 25 |
|           | 3 | 0 | 10 | 27 |

Fig. 3 Number of pointing events recorded per minute in each of the three groups of magpies tested in conditions 2 and 3

The scores per minute are for years 1 and 2 (repeats) combined. Note the decline in number of pointing events with time after detection of the predator. Also note the higher number of pointing events in Condition 3 than Condition 2, taking into account that the scales on the Y-axis differ.
Fig. 4  Number of pointing events performed by each bird in the first minute after arrival on perch
Birds were allocated a number according to time of arrival (X-axis). Note that the first bird to arrive in each group performs more pointing than the second, and so on until the latest arrivals do not point at all, even though they had the same scoring time in which to do so.

across the five-minute trial by individual birds and pointing is not equally distributed among all members of the group but by time of arrival at the scene. First-comers point most, last-comers least. The angle of the substrate on which the magpies perched made no difference to the pointing posture (see Fig. 5), no matter how uncomfortable, i.e., toes placed in same direction as substrate rather than, as normal, in right angle to perching substrate.

2.2  Body posture
Two instances of vigilance behavior (Fig. 2 A) were scored, both in Group 3 and only in Condition 3 (wooded area). In both cases, the behavior was displayed immediately after the magpie had landed to investigate – both individuals eventually turned to a pointing magpie and then changed viewing direction. Exaggerated head movement (Fig. 2 B, described in Section 1.3.2) was scored 4 times in 2 groups (1 and 3) and performed by 3 magpies in the first run of trials in 2003 but not in the following year. Flight intention movements were only scored from 1 bird (Fig.2 C), a one-year-old bird, fledged in the previous breeding season. The posture involving repeated raising of the wings while still looking up lasted for almost an entire minute before the bird, on seeing other magpies land, then began looking in front and around and eventually glanced in the direction of the eagle. It never once pointed.

2.3  Viewing
Looking up instead of forward towards the predator model was scored in 5 cases in Condition 3, including the first year bird described above (flight intention movement) but only in the first set of trials in 2003 (not in 2004). Eye-gaze following was possible to record from the distance of 20 m only if this included an obvious head movement or a turning towards a pointing bird.
Incidents of eye-gaze following, A total of 28 clearly identifiable gaze-following events were scored for all groups in Conditions 2 and 3 over all testing periods and over both years of the experiment, of which 18 (64%) occurred in the first set of trials. Magpies typically engaged in gaze following (watching a pointing magpie) when it first landed. Repeat gaze-following events were recorded in case of 3 magpies that had been observed to use the exaggerated head movement in the first year of

Fig. 5  Angle of stationary viewing and pointing at eagle in relation to available substrate
Image 1 shows the positioning of magpies towards the eagle when natural substrate/shrubs were available as was seen in the original anecdotal observation (this perching substrate happened to be semi-circular; Image 2 shows magpie body positions on benches experimentally set. Normally, perching birds choose an angle for roosting that is in a right angle to the perch so that the digits (toes) can grip around the branch. Regardless of position of substrate for perching, of perch angle or height, the birds continued to point without fail with the beak towards the eagle.
trials and even in several other cases where the viewing direction towards the eagle model had already been established.

2.4 Approach behavior

Swooping behavior was scored only in Condition 1 (open): Mean ± sem number (12.18 ± 2.82) of attack swoops/bird/group of all groups combined during the 5-minute presentation of the wedge-tailed eagle (Fig. 6). Vocalizations were plentiful in all trials.

Silent approaches: In Condition 2, but not 3, there were 1 or 2 magpies in all three groups that fluttered to the ground within 5 m of the eagle model and then quickly flew up again but these few instances were the only approaches attempted. No magpie walked towards the eagle, once on the ground.

2.5 Vocal behavior

This was scored in all trials for the first minute but vocalizations were maintained by the group throughout the 5-minute trial. The number of alarm calls, eagle alarm calls and pointing events were highest in Condition 3 for all three groups (Fig. 7). Condition 1 (open field) slightly reduced the number of vocalizations compared to the other two conditions. The third condition also resulted in a higher proportion of specific aerial/eagle alarm calls. ‘Eagle alarm calls’ constituted between 23.9 and 38.4% of all calls made (Table 2) and most of these were emitted within the first 20 seconds of a bird landing and spotting the eagle model.

Fig. 6 Swooping (attack flights) at the eagle occurred only in Condition 1 (open field)
When the eagle model was placed under foliage (Conditions 2 and 3), no attempts were made to swoop the eagle. Vocalizations continued, however, for the entire 5-minute test period in all conditions.

3 Discussion

3.1 Pointing in a multimodal context

As Table 1 shows, geographic conditions and visibility of the predator determined the behavior and strategy used. The first condition elicited high levels of attack swooping, as expected, and the vocalizations expressed the mobbing intention (see Kaplan et al., 2009). In Condition 2, apart from the stimulus location, the site was generally an open field (good visibility) but the sheltered position of the eagle in two of the three conditions did not allow the magpies to take any of their usual mobbing actions. Nevertheless, they vocalized and also used the pointing gesture. In Condition 3 (wooded area), the number of vocalizations and pointing events were highest for all three groups, as shown in Table 1 and Fig. 7.

Hiding a raptor under a tree that normally glides on thermals and attacks from the air is an artifact and
therefore a very unusual circumstance. The observed instances of looking up, of flight intention movements and of general vigilance suggest that the magpies had instantly understood the general vocal message of extreme danger and that this danger (an eagle) ought to be found at tree height or in the air. Note also that all members of the family group (in all 3 groups) arrived at the testing site within the first 70 seconds of testing, most within the first 60 seconds. It was the very exceptional nature of the event that seemed to require the visual pointing gesture to reinforce the vocal message.

Arousal levels in all trials were very high, reaching stress levels in the third condition, judging by the panting and half open beaks that some showed in the fifth minute of the trial. Equally possible is that the panting towards the end of the five minute period of testing was an indication of physical exhaustion. Some vocal sequences had continued for as long as 5 sec without any apparent breaths or minibreaths in between. High levels of energy (Jurisevic et al., 1999) were needed for the vocal and pointing effort, given that the calls were at frequency ranges to 3.5 kHz and thus at the upper level of the sound production capabilities of magpies (Suthers et al., 2011). A magpie’s typical frequency range for song is 0.8–2.5 kHz. In addition, these alarm vocalizations were of extremely high amplitude (105±5 dB at 10 m distance). The posture adopted for the loudest alarm calls vocalization is usually upright and body even bent backwards. By contrast, the posture of pointing demanded a forward, even crouching, slant to the body (Fig. 1 C) while vocalizing at high amplitude.

All adult magpies eventually found the eagle model even in the third testing condition but, judging by the searching, upward looking and general postures on hearing the vocal signals, it is possible that not all magpies would have detected the eagle without the additional help of the visual information of a pointing magpie.

3.2 Eye-gaze following and pointing- their possible significance

The results presented here showed that magpies followed eye gaze when they followed the pointing magpie’s gaze. One might argue, however, that pointing in magpies may be no more than extensive viewing and high arousal (even though this does not diminish the eye-gaze following) or that the act of viewing and discovering a predator has been adaptive in magpies so that it can be performed relatively automatically, even though the behavior may look complex (Bateson, 2005).

The incessant alarm calling during the trials could be cited in support of the affective state but the findings speak against an instrumental interpretation. One is a consideration for the avian eye and its viewing capacities itself. Birds differ in degrees of binocular and monocular fields of vision. In magpies, eyes are placed laterally and their binocular vision is 28°–34° while their monocular field is over 140° (Rogers and Kaplan, 2005). When they view the predator in the ‘pointing’ position, they do so without moving the head left or right, hence rely on binocular vision. Maldonado et al. (1988) found that chickens and pigeons adopted a frontal gaze for a static or slow-moving stimulus that stabilized the image in the retina, and for a fast-moving stimulus they adopted a lateral gaze that allowed the image to move across the retina. We have already established that magpies use lateralized viewing when confronting a predator (Koboroff et al., 2008). Hence the binocular viewing, especially at a distant object, is a special event not because of high arousal but because magpies need to suppress any action and remain absolutely motionless. For a species that engages in fight rather than flight in agonistic encounters, the lack of motor activity in executing pointing vis-à-vis the eagle, is an act of great physical control. The results have also shown that magpies followed the direction of another magpie’s beak/body by watching a pointing magpie, then looking in the direction of the pointing and then often adopting a pointing gesture themselves.

3.3 Beak pointing as an intentional act

The question remains whether the act of pointing in magpies betrays an ability for cognitive complexity or is merely an adaptive behavior that has contributed to the survival of the species, or alternatively, is an example of ‘instrumental’ pointing. Cognitive complexity is attributed to referential signals only, meaning that a signal is not just the result of an emotive outburst but it is selected because it carries a specific meaning that is understood by the recipient and can be acted upon, and ‘intentional’ when the signaler addresses this to an audience of at least one observer and does not engage in the behavior when thought to be alone (Cartmill and Byrne, 2010; Evans, 1997).

As this paper has argued throughout, the incident of finding a wedge-tailed eagle under a tree and on the ground is a rare event. Its discovery by the entire family group was therefore of urgent importance, and alerting others an important task. Secondly, to adapt a general knowledge to a novel situation, and do so swiftly, would seem to require some cognitive processing. Skeptics of ape and even human infant pointing as a cognitive act
have made the point that one must distinguish between imperative and declarative gestures. Baron-Cohen (1999) argued that simple pointing, called imperative pointing, was not intentional communication but a simple stimulus-response mechanism, while declarative pointing signified an attempt of the signaler to change the mind/cognitive state of knowledge, i.e., required thought (cognitive domain). Even by this stringent definition, it is hard to conclude otherwise than to say that the magpies engaged in proto-declarative acts. Each pointing magpie’s role was clearly to change the state of knowledge of another and it immediately stopped its pointing behavior once the watching magpie had also started viewing the eagle and issued alarm calls. In other words, the pointing act ceased because of another magpie’s changed behavior and not because the arousal diminished. Moreover, the pointing magpies did not point to get something for themselves (such as in begging for food gestures), but to let someone else know of the presence of the eagle.

It is of great significance too that the last two arriving magpies in each group (see Fig. 3) did not adopt a pointing posture at all. Had it been a case of arousal (i.e. instrumental), one would have expected the behavior to continue for as long as the stimulus was visible and in their territory. While swooping behavior continued indeed unabated for 5 minutes in the first test condition, the ‘pointing’ and eye-gaze following dropped off sharply and then stopped once the object for the alarm was detected by everyone. The last two criteria would seem to indicate that the pointing was intentional and referential in the sense that the last magpies had no-one else to inform but the first magpie did not stop until the entire group had spotted the hidden eagle. Moreover, acts involving eye gazing and even pointing may be an important dimension of communication. In some species, such communication has been shown to be cognitively complex (Leavens et al., 2004), especially in social species. Australian magpies are a social species, as was pointed out before, and their survival hinges on cooperation.

Finally, as of 2008, it is now also possible to discuss the discovery of pointing in magpies in a context similar to the ongoing debate of pointing and gestures in primates. In 2008, Prather and colleagues published their discovery of mirror-like neurons in the avian brain involved in song learning. This specific set of neurons responded to primary songs equally when the bird sang them and when it heard them, fulfilling the criteria for mirror neurons identified in primates a decade earlier and in humans only very recently. In the very same year, Feenders and colleagues (2008) proposed a motor theory for the origin of vocal learning in birds, suggesting that the brain areas specialized for vocal learning in vocal learners evolved as a specialization of a pre-existing motor pathway that controls movement. In songbirds, parrots, and hummingbirds (all vocal learners), cerebral vocal learning nuclei adjacent to discrete brain areas are active during limb and body movements. Activation in the adjacent areas correlated with the amount of movement performed and was independent of auditory and visual input (Feenders et al., 2008).

These recent discoveries give some biological underpinning to the pointing behavior in magpies. As a pre-speech ‘performative’ (term used by Bates et al. initially in 1975) and in conjunction with (referential) eagle-alarm calls, it may well be evidence of complex cognition by meeting stringent criteria of an imperative (rather than instrumental) act of pointing, as defined before. It was also shown to be intentional. The discovery of beak pointing in magpies stands in a very long tradition of debate on pointing, cognition, speech production and hemispheric specialization but almost entirely on its own in research on avian species.

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