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Elephants classify human ethnic groups by odor and garment color

Lucy A. Bates[1], Katito Sayialel[2], Norah Njiraini[2], Cynthia J. Moss[2], Joyce H. Poole[2] & Richard W. Byrne[1]

[1] *School of Psychology, University of St Andrews, St Andrews, KY16 9JP, UK.*

[2] *Amboseli Trust for Elephants, PO Box 15135, Langata 00509, Nairobi, Kenya.*

Corresponding author: Richard W. Byrne. Email: rwb@st-andrews.ac.uk

Tel: +44 1334 462051   Fax: +44 1334 463042

Running Title: Elephants distinguish between human ethnic groups

Animals can benefit from classifying predators or other dangers into categories, tailoring their escape strategies to the type and nature of the risk. Studies of alarm vocalizations have revealed various levels of sophistication in classification [1-5]. In many taxa, reactions to danger are inflexible, but some species can learn the level of threat presented by the local population of a predator [6-8] or by specific, recognizable individuals [9-10]. Some species distinguish several species of predator, giving differentiated warning calls and escape reactions; here we explore an animal's classification of sub-groups within a species. We show that elephants distinguish at least two Kenyan ethnic groups, and can identify them by olfactory and color cues independently. In the Amboseli ecosystem, Kenya, Maasai warriors demonstrate virility by spearing elephants (*Loxodonta africana*), but Kamba agriculturalists pose little threat. Elephants showed greater fear when they detected the scent of garments previously worn by Maasai than by Kamba men, and reacted aggressively to the color associated with Maasai warriors. Elephants are therefore able to classify members of a single species into sub-groups that pose different degrees of danger.

Results and Discussion

Suricates (*Suricata suricatta*), prairie dogs (*Cynomys gunnisoni*), and several species of primate are known to classify different predator species into categories depending on the type and nature of the risk posed [2-5]. Having the ability to classify all members of a single predator species into sub-groups, and thus be able to respond appropriately to each, would be of material benefit whenever a potential predator exists in sub-populations that present different degrees of risk. The predator that most obviously shows this pattern is man. In many areas of the world, human populations include ethnic groups that engage in hunting and others that, in the same areas, focus their lives on agriculture or pastoralism. It would pay any prey species living in these areas to use ethnic sub-group classification as a basis of their anti-predator response.

African elephants offer a good opportunity to test for this kind of predator sub-classification. In the Amboseli ecosystem, Kenya, elephants encounter several types of people, presenting different levels of risk, including but not limited to: the Maasai, cattle-herding pastoralists whose young men spear elephants (although prohibited, elephant spearing is a regular, low frequency occurrence in the area [11-12]); the Kamba, the most numerous of the agricultural and village-living peoples who today pose little threat to elephants; tourists and researchers. Studies aimed at understanding conflict between humans and elephants propose that elephants may respond differently to Maasai men than other people [13-14]. Furthermore, elephants show signs of sophisticated classification in other domains, reacting to bones of dead elephants in a different way than to those of other large animals [15], and showing extensive vocal recognition within their complex social hierarchies [16-17]. We experimentally presented elephants with human artefacts in order to test the hypotheses that: (1)

elephants classify humans into distinctive subgroups that vary in level of risk to them, in particular identifying the Maasai; (2) elephants use olfactory and visual cues independently in classifying human groups; (3) individual or family history of spearing affects the extent and nature of the reaction towards cues signalling Maasai.

To investigate use of olfaction, we used a within-subjects design to compare the reaction of 18 elephant family groups to three different types of garment: clean, unworn, red cloths; red cloths worn by adult Kamba men for a period of five days; and red cloths worn by adult Maasai men for a period of five days. The three garments were presented to each elephant group on different occasions, separated by at least a week and counterbalanced for order of presentation. Reaction was assessed by four measures: time spent stationary after first smelling the cloth; travel speed in the first minute of movement; distance moved away from the cloth in the first five minutes; and time taken to relax. Distances from the cloth were estimated in the field before and after presentation. Reaction times were measured from videotape recorded continuously during each trial. In every trial, the point when an elephant first detected the scent of a cloth was clear, as it would pause with head up and trunk curled upwards, pointed in the direction from which the scent came (Figure 1). The time elapsing from this moment of detection until the group began to move was similar for the three types of cloth (Figure 2A), suggesting that differences in reaction were not a function simply of the strength of a scent, but rather depended on its nature. After travel ceased, individuals might still show tension by their erect head posture, sniffing, and close proximity to others; we recorded that a group had relaxed when the elephants spread out and began feeding, dust-bathing, or resting with heads lowered [18].

Elephants distinguish Maasai from other humans by olfaction

Travel speed, distance traveled and time taken to relax differed strikingly between the three red cloth types presented (MANOVA, $F_{(8,62)}$=11.786, p<0.001, Wilks λ=0.157, see Figure 2 for details of pairwise comparisons). When presented with a cloth previously worn by a Maasai man, elephants traveled significantly faster in the first minute after they began to move; traveled a significantly greater distance away from the cloth in the first five minutes; and took significantly longer to relax after travel ceased than they did when presented with either the Kamba-worn or the unworn cloths (Figure 2B-D). In every presentation of the Maasai cloth, the initial direction of travel was directly away from it, in the downwind direction (+/- 85^o from the eight-point compass direction of the wind). Although reactions to a cloth worn by a Kamba man were significantly more muted than reactions to a Maasai-worn cloth, they were nevertheless significantly stronger on these measures than reactions to an unworn red cloth. When presented with an unworn red cloth, elephants moved significantly slower, for significantly shorter distances, and relaxed significantly quicker than they did to either the Maasai- or Kamba-worn cloths. When presented with the unworn cloth, groups were also less likely to travel downwind from the cloth than when presented with worn cloths (Chi square test, χ^2=3.943, df=1, p=0.047).

Since elephant groups reliably headed directly away (downwind) from worn cloths that they scented, they never came within 10 m of the experimental stimuli and gave no sign of seeing them. The results therefore imply that elephants can classify members of a potential predator species into sub-groups based on olfactory stimuli alone, without prior familiarity of the specific human individuals involved.

Detection of human scent, and in particular the difference between the two local peoples, may have been based on a number of olfactory cues. As well as possible differences in pheromonal profile, the diets of Maasai and Kamba peoples differ strikingly. Maasai consume substantial amounts of milk and occasionally cattle blood and meat [19], whereas Kamba diet mainly comprises meat, vegetables and maize meal. These dietary differences may be reflected in chemical composition of body odor. Furthermore, the Maasai are pastoralists so odors of cattle permeate their villages, and they use ochre and sheep fat in body decoration, unlike the agricultural Kamba.

Elephants move to different habitats when presented with different stimuli

Movement in response to the scent of a garment worn by a Maasai was not simply *away* (downwind) from the olfactory stimulus, but also *towards* a particular habitat, in the sense that elephants' flight tended to continue until they reached elephant grass vegetation over 1m in height. All experimental trials with Maasai-worn garments ended in this habitat, whereas with an unworn cloth, this was rarely the case; in trials with Kamba-worn garments the tendency to seek tall grass was intermediate (Figure 3). With both Kamba and Maasai garments there was a significant increase in habitat height from where the cloth was first detected to where the elephants finally relaxed, whereas with an unworn cloth no such difference was seen (Kamba garment, median habitat height, initial 0.20 m, final 0.55 m, Wilcoxon test, $z=-2.761$, $p=0.006$; Maasai garment, median habitat height, initial 0.35 m, final 1.25 m, Wilcoxon test, $z=-3.740$, $p<0.001$; unworn garment, median habitat height, initial 0.30 m, final 0.30 m, Wilcoxon test, $z=-1.00$, $p=0.317$). Arriving in denser, taller habitat is not an inevitable result of movement: only 7% of the Amboseli National Park, in which all trials were conducted, is covered with elephant grass [K. Lindsay, personal communication]. Rather, it seems that when alarmed by olfactory detection of humans, especially Maasai, elephants seek denser, taller habitats.

Direct experience of spearing does not determine reaction

We predicted individual or family history of spearing would affect the extent and nature of elephants' reaction to Maasai odor cues. However, we found no overall effects of spearing history on strength or type of reaction. This is despite considerable variation in past aversive interactions with Maasai among the elephant groups tested. Two elephants tested were known to have been highly aggressive towards Maasai cattle, and seven of the family groups tested included individuals that had experienced multiple cases of spearing to themselves or their immediate family during the last 30 years. In contrast, three groups were composed of individuals that are not known to have experienced spearing of any individual in their family over this period. We divided all the elephant groups we tested into three categories of different experience with spearing. Elephant group reactions, in terms of speed of travel, distance moved and time to relax, did not differ with their spearing history (mixed MANOVA, main effect of spearing history on elephant reactions: $F_{(6,26)}=0.637$, $p=0.70$, Wilks $\lambda=0.760$). Elephant groups in all three categories showed a similar pattern of reaction to the three cloth types (interaction between spear history and cloth type: $F_{(12, 20)}=0.673$, $p=0.757$, Wilks $\lambda=0.508$). Reactions were strong, even in groups with the least experience of spearing, suggesting that social learning is very effective in transmitting knowledge of Maasai people and the associated emotional responses throughout the local elephant population.

Although there were no overall differences in reaction to the cloth types *between* categories of elephant groups with different spearing experiences, there was variation *within* the category of greatest spearing experience, where individuals have personal experience of being speared. The variance in travel speed and distance moved away from the Maasai-worn cloth was large in this group and significantly greater than the variance seen in elephant groups with low or medium-rated experience of spearing (Levene's test of homogeneity of variance on un-transformed data between high, medium and low spearing experience groups: travel speed: $F_{(2, 16)}=14.462$, $p<0.001$; distance moved: $F_{(2, 16)}=6.036$, $p=0.011$. Pairwise comparisons with Bonferroni corrections, travel speed: high: low experience; $p<0.001$, high: medium experience; $p=0.004$; distance moved: high: low $p=0.007$). Elephant groups with personal experience of being speared did not all react in the same way to the scent of a Maasai-worn garment, some moved away very quickly, others much slower; and some moved large distances, others much shorter. This suggests that the effect of spearing incidents on subsequent reactions to Maasai encounters is modulated by individual differences among elephants [20].

Elephants react aggressively to visual cues associated with Maasai

In this area of Kenya, traditionally dressed Maasai characteristically wear red, whereas members of other ethnic groups wear a wide range of colors, including much paler garments than any worn by Maasai. We used this difference to investigate whether elephants can use garment color as a cue to classify humans, in the absence of scent differences. We compared elephant reactions to red versus white cloths, using clean, unworn cloths in a between-subjects design. Only trials in which one or more of the elephants stopped and looked at the cloths were included in the analysis. Individuals traveled towards the cloth and came close to it, and their sudden arrest of body movement and head orientation toward the cloth indicated that they had seen the stimulus (mean distance of visual detection: red unworn cloth 6.4 m [+/- 1.5 m]; white unworn cloth 6.8 m [+/- 3.8 m]). The total time they spent exploring the stimulus, either standing still or physically interacting with the cloth, was similar for both these unworn cloth types (Mann Whitney U test, U=20.00, p=0.739), indicating similar levels of interest, but the *type* of reaction differed. Significantly more aggressive displays [18] were directed towards the red cloth than the white (Mann-Whitney U test: U=4.00, p=0.012, Figure 4). It is important to note that this effect is in the reverse direction to the visual salience of the cloths: elephants are dichromats [21] for whom red is a relatively drab hue. Whereas elephants had reacted with fear to the scent of Maasai-worn cloths, in this visual case their reaction was to threaten. More experiments are required to determine if any other colors elicit this type of aggressive reaction.

The apparent difference in emotional reaction to visual as opposed to olfactory cues may be explained by the difference in strength of evidence implicating the presence of Maasai. Elephants possess a large olfactory bulb [22], so if a Maasai warrior were present and close by at that time they should readily be detected by olfaction. In experimental trials with unworn cloths, therefore, the lack of human body scent indicates that present danger is small because the person is no longer present in that area. Thus, when an unworn red garment is seen but Maasai scent is not detected, the consequent lack of fear allows the elephant's antipathy to dominate. But when 'Maasai' has been signaled by olfaction, a Maasai person must be present, possibly close by, and the danger of that situation triggers a reaction dominated by fear.

The ability to use visual as well as olfactory cues to the possible presence of danger suggests that elephants have a general ability to interpret perceptual cues to the presence of predators. In contrast, vervet monkeys did not show an ability to interpret indirect cues to danger when tested experimentally [23]. When researchers simulated a python's characteristic tracks, or a leopard's characteristic caching of kills among tree-branches, the monkeys showed no sign of realizing that major predators might be close by. This association may be difficult to establish because the track and signs can occur temporally distinctly from perception of the predator species itself.

Conclusion

The ability to classify members of a predatory species into sub-groups offers adaptive advantage when the predator exists in sub-populations that present different degrees of danger. Different human ethnic groups present varying risks to elephants, and we have shown that the elephants of Amboseli National Park do classify and respond to these ethnic groups differently. Elephants reacting to information in odors showed most fear to Maasai-worn cloths, running away quickly and downwind until they reached tall elephant grass, remaining tense and alert even after reaching the protection of this denser habitat. The same elephants showed least fear to the unworn cloths. They were slightly wary of the scent of these cloths, generally moving away, but much more slowly. They did not seek taller grass in which to hide, and soon relaxed. The response to scenting cloths worn by Kamba men was between these two extremes. Fear of Maasai men was not specific to elephants with personal experience of spearing: elephants with low or no experience of spearing showed similar reactions. However, for those with personal experience of spearing, the episode apparently affected individuals differently. When presented with visual cues associated with Maasai men, in the absence of olfactory cues, the elephants showed aggression.

Elephants therefore show remarkable discriminatory abilities: able to use olfaction *and* vision, independently, to classify garments according to their likely human wearers, and vary their reactions appropriately to the likely danger. Given the potential adaptive benefit of classifying a predator species into sub-categories, we expect that this ability will prove to be widespread among animals with appropriate perceptual and cognitive capacities.

Supplemental Materials

Details of the experimental procedure, ethical considerations and analysis employed can be found in the supplemental data.

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Figure 1: Examples of elephant reactions to garments worn by Maasai.

The top panel shows the high carriage of head and tail, and the uplifted trunk of elephants that have just detected a cloth's scent. The lower panel shows elephants as they run downwind from the location of a cloth: note the bunching of the group and continued high head and tail.

Figure 2: Reactions of elephant groups to cloths differing in scent.

(A) Time spent stationary after first smelling the three cloth types, (B) travel speed in the first minute, (C) distance moved away from the cloth in the first five minutes, (D) time taken to relax. In each case, mean values and 95% confidence intervals are shown. Pairwise comparisons of log-transformed data (using a Bonferroni correction for multiple comparisons) were used to examine the effects. There were no differences in the time spent stationary after first smelling the cloth within the three cloth conditions (panel A, mean differences: Maasai / Kamba 0.078; Maasai / unworn 0.100; Kamba / unworn 0.178; for all values $p>0.98$). Significant differences were found in the travel speed (B), distance moved (C), and time taken to relax (D) between the Maasai- and Kamba-worn cloths (mean differences: travel speed 0.270, $p=0.014$; distance 0.656, $p<0.001$; relaxation 0.389, $p<0.001$), between Maasai-worn and unworn cloths (mean differences: travel speed 0.645, $p<0.001$; distance 1.299, $p<0.001$; relaxation 1.011, $p<0.001$), and between Kamba-worn and unworn cloths (mean differences: travel speed 0.375, $p=0.001$; distance 0.643, $p<0.007$; relaxation 0.622, $p<0.001$).

Figure 3: Habitat choice in response to experimental trials.

Bars show the number of trials that ended with the elephants resting in elephant grass after detection of Kamba-worn, Maasai-worn or unworn cloth. White bars indicate trials that ended in elephant grass, solid bars show trials that ended in any other habitat type. The association between presentation condition and final habitat was significant (Chi square test, χ^2=33.246, df=2, p<0.001).

Figure 4: Aggressive displays to cloths of different color.

Box plots indicate displays directed at unworn red or unworn white cloths, showing median values illustrated with the bold line, inter-quartile range, and range.