VISUAL AND OLFACTORY RECOGNITION OF FAMILIAR

HUMANS AND ELEPHANTS BY AFRICAN ELEPHANTS

By

Victoria Perret

Preston G. Foerder
Assistant Professor of Psychology
(Chair)

Irene N. Ozbek
Professor of Psychology
(Committee Member)

Amye R. Warren
Professor of Psychology
(Committee Member)

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ABSTRACT

African elephants distinguish between familiar and non-familiar conspecifics through olfaction and human ethnic groups through vision and olfaction. We investigated whether elephants recognize individual familiar humans and elephants through vision and olfaction in two captive African elephants. After training, visual recognition was tested over three sessions with three keepers holding a photo array with two photos. Using similar methodology, olfactory recognition was assessed using a t-shirt worn by an individual as the sample above the photo array. Visual recognition of familiar elephants was assessed matching a photo of one side of a familiar elephant to a photo array of two photos of the other side of elephants. Throughout the study, recognition was determined if the elephant touched the correct photo significantly above chance. Results indicate one of the elephants may be able to recognize familiar keepers through visual and olfactory cues due to significant performance above chance in multiple sessions.

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CHAPTER I

INTRODUCTION

Discrimination is a cognitive process that allows animals to distinguish between shapes, sounds, and individuals (Delius, 1992; Smith et al., 1995; Taylor & Davis, 1997). Concerning discrimination of individuals, intraspecific discrimination (i.e., discriminating familiar or unfamiliar members of the same species) is distinguished from interspecific discrimination (i.e., discriminating between the same and different species). Furthermore, intra- and interspecific recognition, refers to knowing a smell or other cue of an individual belongs to that specific individual of the same or different species (Watanabe & Aust, 2017). Many species of animals can discriminate or recognize familiar and unfamiliar conspecifics (i.e. members of the same species), familiar and unfamiliar humans, and specific individuals of the same or different species (Coulon, Baudoin, Heyman, & Deputte, 2011; Marzluff, Walls, Cornell, Withey, & Craig, 2010; Taylor & Davis, 1997; Vincze et al., 2015). African elephants (*Loxodonta africana*) discriminate between olfactory cues of kin and non-kin as well as between local ethnic groups (Bates et al., 2007; Bates et al., 2008). However, research has not yet shown if African elephants exhibit intra- and interspecific recognition on an individual level.

Intraspecific Recognition

Intraspecific discrimination is the ability to tell the difference between members of one's own species. For instance, paper wasps (*Polistes fucatus*) reside in stable colonies and are known to chase off members of different colonies by discriminating between chemical signals of their

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own and other colonies (Tibbetts, 2002). Intraspecific recognition, however, refers to knowing that a smell, visual cue, call, or other stimulus belongs to a specific member of your own species (Watanabe & Aust, 2017). Paper wasps also have unique facial and abdominal markings that are used for individual recognition. If the markings on an individual are altered, individuals are not automatically run off as they would be if they were from a different nest. Instead, the altered wasp receives increased amounts of aggression from nest-mates. The amount of aggression received decreases over time, indicating that nest mates now recognize the altered wasp as having a certain standing in the hierarchy (Tibbetts, 2002).

Cattle (*Bo taurus*) display intraspecific discrimination of those from their own or a different herd early in life. Young heifers were shown life-size 2D photos of familiar and unfamiliar cows while their responses were recorded. The heifers spent more time observing, exploring, sniffing, and licking the familiar cow photos. In addition, the heifers were more likely to approach the familiar cow's photo before approaching the unfamiliar cow's photo. Knowing related cattle within their herd is important later in life as it helps cattle avoid inbreeding (Coulon et al., 2011).

Intraspecific recognition can be studied using stimuli from one sense or multiple senses. When using stimuli from multiple senses, there is an interaction across those modalities (cross-modal) and this interaction can be helpful in determining if an individual can recognize other specific individuals (Levine, 2000). Cross-modal recognition can be helpful when determining if a subject can recognize specific individuals. Proops, McComb, and Reby (2009) tested domestic horses (*Equus caballus*) to see if they form cross-modal representations of familiar horses. To determine if horses formed these representations, a familiar horse stood in front of a subject for a minute and was then led away. After the horse was out of sight for 10 seconds, a whinny from

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the horse seen or a different familiar horse was played. During the incongruent trials (when the subject saw and heard different horses), horses looked towards the sound source sooner and looked longer than when both visual and auditory stimuli were from the same horse. This implies that horses form cross-modal representations of other horses since the unexpected sounds caused greater reactions.

An example of recognition using only one sensory modality is seen in northern fur seal pups (*Callorhinus ursinus*) that are left by their mothers for up to a week while they fish. Upon returning mothers must find their pups mainly via vocal calls. Pups and mothers respond more to vocal calls from their kin than to calls from other familiar seals. The recognition of vocal calls from mother to pup and pup to mother aid in reuniting kin when the mother returns to the beach after feeding. This intraspecific recognition of a mother's call is imperative to a pup's survival because if they do not recognize their mother's call, they may not find her to nurse (Insley, 2001).

In addition to knowing their own social group, intraspecific recognition lets individuals know where their group stands in a dominance hierarchy. Rhesus macaques (*Macaca mulatta*) were presented with the scent of a female macaque from their own or a different social group. When presented olfactory cues from a different social group, macaques placed their nose closer to the scent for longer periods of time and initiated in more olfactory related behaviors (i.e, sniffing and licking). Additionally, when the odor was from a female in a higher ranking social group than the subject's, there was a greater response than if the odor was from a female in a lower ranked group (Henkel, Lambides, Berger, Thomsen, & Widdig, 2015).

Interspecific Recognition

Interspecific discrimination is the ability to distinguish between members of the same and different species. Some interspecific recognition research tests the ability of animals to discriminate between specific individuals of a different species. Giant pacific octopuses (*Enteroctopus dofleini*) are able to recognize a human that fed them and a human that irritated them. Anderson, Mather, Monette, and Zimsen (2010) observed the reactions of eight captured octopuses to two individual humans. Displays such as aiming jets of water towards an object, changing pattern or color (specifically presence of a dark eyebar, a defensive behavior), and changes in respiration rate indicate arousal in octopuses. Octopuses also move towards positive stimuli. During this experiment, one person fed an octopus while the other person irritated the subject with a bristly stick. By the end of the experiment, octopuses showed different behaviors towards each of the humans. Octopuses moved away from and pointed their water jets towards the individual who irritated them and displayed a dark eyebar. However, when seeing the person that fed them, octopuses moved towards the human and pointing their funnels away. These different behavioral patterns suggest that the octopuses recognized the person that fed them as opposed to the person that irritated them.

Vincze et al. (2015) suggested that urban, as opposed to rural, house sparrows (*Passer domesticus*) would be better able to distinguish between familiar and non-familiar individual humans. To test this hypothesis, an experiment was conducted with three conditions: researchers wore a mask and stood near the birds, wore a different mask and threatened the birds, or wore another different mask and stood near the birds. However, only rural house sparrows showed increased avoidance and hiding behaviors towards hostile or unfamiliar masks compared to non-hostile masked individuals. Urban birds showed no difference in their behaviors towards any

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masks. This result may be due to the rare occurrence of encountering the same individual twice in urban environments making human encounters in rural environments of greater importance. Additionally, human interactions in rural environments are more likely to be either hostile or benevolent than in urban settings. Therefore, it may be more beneficial for rural sparrows to distinguish individual humans.

Like the rural house sparrow, American crows (*Crovus brachyrynchos*) may also be able to recognize individual humans. Marzluff et al. (2010) sent researchers in a caveman mask and sun hat out to catch and band wild crows at various sites. The mask assured that these crows were being caught by a novel, dangerous individual. Upon returning to the capture site researchers interacted with the crows in different conditions: wearing the initial dangerous mask and hat combination; wearing just the dangerous mask; wearing just the hat; wearing the dangerous mask inverted; wearing a neutral novel mask; or wearing no mask. When crows saw the dangerous mask in any form, they were more likely to scold that individual than unmasked or neutral masked individuals. The scolding behavior remained for over 2 years after the initial capture implying a lasting recognition of threatening humans. This study shows that American crows may be able to recognize individual humans that pose a threat through visual cues alone.

Cross-modal recognition of familiar and non-familiar humans has been shown in domestic horses. To test this, a familiar or novel person passed by and pat the subject. The person then walked out of sight from the horse and a voice recording from the person they just saw or the other (either familiar or novel) person was played. During incongruent trials, horses looked quicker and more often towards the sound of the voice. They also looked longer when petted by the familiar person and heard the unfamiliar person. These results suggest that horses can recognize familiar humans through multiple senses and can recognize when a presented

auditory cue is not of the familiar individual, much like they do for familiar horses (Lampe &

Andre, 2012).

Two squirrel monkeys (*Saimiri sciureus*) were tested using a cross-modal design to see if they could discriminate between their primary and secondary keepers. The primary keeper had daily interaction with the subjects for approximately four years at the time of the study and the secondary keeper only interacted with the subjects when the primary keeper was not there. To test the recognition abilities of the monkeys, a keeper's face was shown on a screen. After it disappeared, an audio recording of that keeper or the other keeper was played, and the monkey pressed a lever that corresponded with the primary or secondary keeper. In trials in which the face and voice presented were from the same keeper, the subjects only correctly matched the primary keeper at greater than chance levels. The subjects may have had a stronger mental representation of their primary keepers. Primary keeper recognition is indicated by the fact that they also picked the lever corresponding to the primary keeper at greater than chance levels when seeing the secondary keeper, but heard the primary keeper. Whenever any presented stimulus was of the primary keeper, the subject was likely to pick the primary keeper's corresponding lever. This research showed that the subjects formed cross-modal representations of their primary keeper and could identify them based on presentation of either modality (Adachi & Fujita, 2007).

Gothard, Brooks, and Peterson (2009) examined macaque monkeys' ability to discriminate conspecific individuals and human individuals. Macaques spent more time examining the eyes on the faces of conspecific individuals. When viewing human faces, more time was spent viewing other areas of the face implying non-species discrimination.

In a cross-modal, matching-to-sample procedure, Hashiya (1999) showed that a chimpanzee (*Pan troglodytes*) could match human, chimpanzee, or object sounds with a picture of what produced that sound. In a basic matching-to-sample procedure a stimulus (e.g., a picture), serves as the sample and is shown to the subject who then must select the matching picture from an array of pictures (Powell, Honey, & Symbaluk, 2013). In this experiment, a human voice, chimpanzee vocalization, object sound, or bird song was played. Then, a pair of photos was shown to the subject. The pair of pictures consisted of the matching picture and one from the same or different category. The subject correctly matched object sounds, human voices, and chimpanzee vocalizations at a greater than chance level when the array of pictures consisted of the correct image and a picture from a different category. However, she was unable to discriminate between familiar chimpanzee voices when two chimpanzee pictures were shown. The subject could successfully recognize the human that matched the voice and the sound that matched the object when the array of photos was from the same category; however, this was likely because she had received previous training with human voice and object sound stimuli. Although the subject struggled with intraspecific recognition, she did display an ability to discriminate between her own species and humans as well as an ability to discriminate between individual humans.

African Elephant Senses

Most of the previous examples concern recognition using vision and auditory stimuli. This is mainly due to primates, house sparrows, and crows relying on their vision and hearing and possibly in part due to them having proportionately smaller olfactory bulbs than other animals (Griggio, Fracasso, Mahr, & Hoi, 2016; Henkel et al., 2015). These species are also

microsomatic, having a relatively poor sense of smell, therefore possibly leading to fewer studies on their olfactory abilities. African elephants are macrosomatic due to their large olfactory lobe and bulb as well as the extreme number of olfactory receptors (Ngwenya, Patzke, Ihunwo, & Manger, 2011; Shayan-Norwalt, Peterson, King, Staggs, & Dale, 2010). Research has found that African elephants have over 2,000 olfactory receptor genes, which is approximately twice as many as any other mammal studied. Olfactory receptors detect specific odors in an animal's environment (Niimura, Matsui, & Touhara, 2014). These receptors then send sensory input to the olfactory bulb where it is processed into perceived smells (Ngwenya et al., 2011).

African elephants' olfactory abilities play a significant role in their fitness, the ability to survive and reproduce. Unlike most other animals, which sense pheromones through the accessory olfactory bulb, elephants use their olfactory bulb for pheromone detection to gather mating information from another elephant's urine. Female elephants show strong reactions to the chemicals and hormones present in a male's urine during musth while males sense an increase of pheromones in female urine leading up to ovulation. Elephants have the capability of distinguishing between possible receptive mates and can possibly form olfactory representations of others (Rasmussen, Lazar, & Greenwood, 2003).

As an example of elephant olfaction sensitivity, Miller and colleagues (2015) examined whether African elephants are able to identify the smell of TNT which is commonly used in landmines. The natural habitat of the African elephants in Angola was the site of a civil war from 1975 until 2002; many landmines remain buried underground as part of the aftermath. Migratory patterns of the elephants changed following the war, possibly to avoid the areas where landmines may have been buried. In order to tell if elephants are able to detect this specific smell, Miller et al. (2015) trained three domesticated elephants to identify the smell of TNT and to alert

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researchers if they sensed the target smell as opposed to a distractor odor. During the testing phase, elephants identified the target odor 100% of the time it was present and an alert was given for distractor odor only once.

Although African elephants primarily rely on their olfactory sense, they also use their visual system for recognition (Ngwenya et al., 2011). Elephants are arrhythmic; they are active during both day and night and have a visual system that adjusts according to the time of day. The elephant visual system is comparable to humans in that pigments recognized during the day may be similar to that of human dichromatic deuteranopes (red/green colorblind) (Yokoyama, Takenaka, Agnew, & Shoshani, 2005). As opposed to humans, elephants have two fovea, one directed toward the tip of their trunk and the other facing outwards (Pettigrew, Bhagwandin, Haagensen, & Manger, 2010). Their multiple fovea allow them to recognize visual social displays and focus on eating and manipulations with the trunk (Shayan-Norwalt et al., 2010). The outward facing fovea may not only help to distinguish between social displays but to discriminate between who is enacting the display. Additionally, there is a third main area consisting of a band of photoreceptors focused towards the horizon which helps to identify predators in the area (Pettigrew et al., 2010).

African Elephant Discrimination and Recognition

Not only are elephants able to determine receptive mates from olfactory urine cues, but they may also be able to use these cues for intraspecific recognition. Bates et al. (2008) placed the urine of one elephant in the path of another walking elephant. The sample presented either belonged to an elephant that was non-kin, kin but far away, kin and walking ahead, or kin and walking behind. Elephants reached their trunks to the sample most for kin that were walking

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behind as well as kin that were not present. Kin walking behind samples presented potentially surprising information to the elephant that came across the urine. This finding may indicate that not only are elephants able to recognize others based on olfactory cues in their urine but that they may have an idea about the location of other known elephants.

Some local human ethnic groups attack wild elephants in Kenya's Amboseli National Park. However, not all groups present in the area pose a threat. Kamba men, who lead primarily agricultural lifestyles, do not present a danger to the local elephant population. Maasai men, however, use the land for grazing and a water source for their cattle. When the space is shared by elephants and Maasai cattle, conflict may occur. During this conflict, elephants may be speared and left wounded or dead (McComb, Shannon, Sayialel, & Moss, 2014). Bates et al. (2007) examined if elephants could discriminate between the two groups through olfactory and visual cues. Maasai and Kamba men were asked to wear a red garment for three days so that their scent would spread to the fabric. A Maasai, Kamba, or odorless garment was presented near an elephant family group and the group's reaction behaviors were observed. When the Maasai odor was recognized, elephants retreated at a quick average pace of .8 m/s and took an average of 10 minutes to resume pre-odor behavior. Family groups also retreated when recognizing the Kamba odor yet did so at a slower pace, around .4 m/s, and traveled a shorter distance. The average time it took to calm down was also significantly shorter than when presented with the Maasai odor, around 4 minutes. If a garment with no odor was presented, elephants would slightly retreat and subsequently resume pre-movement behaviors. Red cloth was chosen for the garments as red is typically worn by Maasai men in the area. Other groups in the area wear other colors of clothing and there is no particular color associated with Kamba men. When elephant groups were shown a red cloth, they were more likely to exhibit aggressive displays than when shown a white cloth. In

other research, researchers played recordings of males and females of both groups. When elephants heard voices of Maasai males, they retreated farther more quickly, and appeared to smell and listen longer than when hearing male and female Kambas and female Maasais (McComb et al., 2014). These results show that elephants discriminate between different groups of people through cues of varying modalities.

Present Study

African elephants have been shown to recognize groups of humans based on visual and olfactory cues and discriminate between kin and non-kin elephants through olfactory cues. However, there is a lack of research on whether or not African elephants are capable of visual and olfactory recognition on an individual level both intra- and interspecifically. I conducted research using a matching-to-sample design in which a visual or olfactory cue from a familiar human or elephant served as the sample for a photo array consisting of two photos of individuals from the same species (human or elephant). I hypothesized that elephants are able to 1) correctly match a photo of a familiar individual to a visual cue (actual person), 2) correctly match a photo of a familiar individual to an olfactory cue (a t-shirt) of that individual and 3) correctly match a photo of a familiar elephant to a visual cue (photo) of that familiar elephant.

CHAPTER II

METHODOLOGY

General Method

Subjects and Housing

Three African elephants (*Loxodonta africana*) are housed at Zoo Knoxville in Knoxville, TN: two females – Edie, 10,106 lbs, 35 years old and Jana, 9,962 lbs, 31 years old; one male – Tonka, 14,458 lbs, 37 years old. For the current study, only Edie and Tonka served as subjects. Jana was excluded from the study due to aggressive behaviors shown during the training phase.

Subjects were tested in the indoor barn under protected contact. Protected contact refers to how the animals are housed. In this style, keepers always remain outside of the animal's enclosure and the animal's participation in any type of training or activity is completely voluntary (Brown, Wielebnowski, & Cheeran, 2008). Because participation in the experiment was voluntary, as well as novel for the subjects, this may have served as additional enrichment on days research was conducted.

The indoor elephant barn consists of two separate pens to separate the male and females. Subjects were located behind the gates but could reach their trunks through the bars. The second story of the barn consists of half walls overlooking the pens. From this area, researchers observed the experiments while remaining out of view of the subjects and keepers.

Materials

All sessions were recorded with a Canon Vixia HFR400 camcorder on a tripod. The camera was placed on the second-floor overlook so it could be positioned to record the subject's trunk and experiment. During experiments 2 and 3, a GoPro Hero3+ was attached to the easel to provide an additional viewpoint of the subject's trunk.

Throughout the study, correct responses were rewarded with small food rewards. These food rewards were preferred foods consisting of small pieces of fruits or vegetables that were only used during sessions.

An apparatus was constructed out of ⅛ in. thick plywood to hold photo choices during all experiments. For experiments 1 and 2, the board measured 42 in. x 12 in. and for experiment 3, 42 in. x 24 in. All boards were covered in clear vinyl. A line of white duct tape was placed down the center of the board to distinguish sides (see Figure 2.2). Two handles were attached to the back for the keepers to hold the boards without potential cueing in experiment 1. During experiments 2-3, the boards were placed on an easel. Subjects are familiar with the easel since it is used for some of their enrichment activities such as painting.
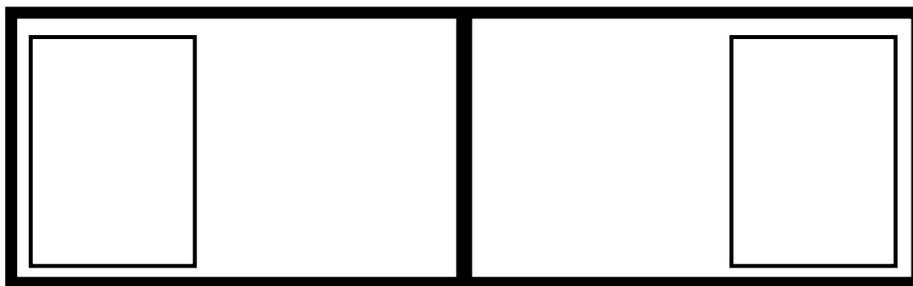
Figure 2.1 Design for Photo Holding Apparatus

Initial Training Phase

The study began with a training phase during which the head keeper first held a photo of herself in her hand and rewarded the elephant when they touched it. She then held the apparatus with only her photo on the left or right side (see Figure 2.1). The photo was presented on either side in a randomized order. Each time the elephant touched the photo they received a small food reward. A trial was defined as a success or failure on the task, determined if the elephant reached towards the correct photo. Sessions lasted for either 30 minutes or until all trials were completed; whichever occurred first. Initially, 20 trials were planned per session but the elephants finished these quickly and the number of trials was increased to 40 per session. The training phase consisted of 3 sessions at which point subjects performed at least at a 60% success rate. This training was only conducted for before experiment 1 and was expected to carry over through all subsequent experiments. The photo of the head keeper did not appear on a photo board after training since elephants had now learned to point towards her picture.
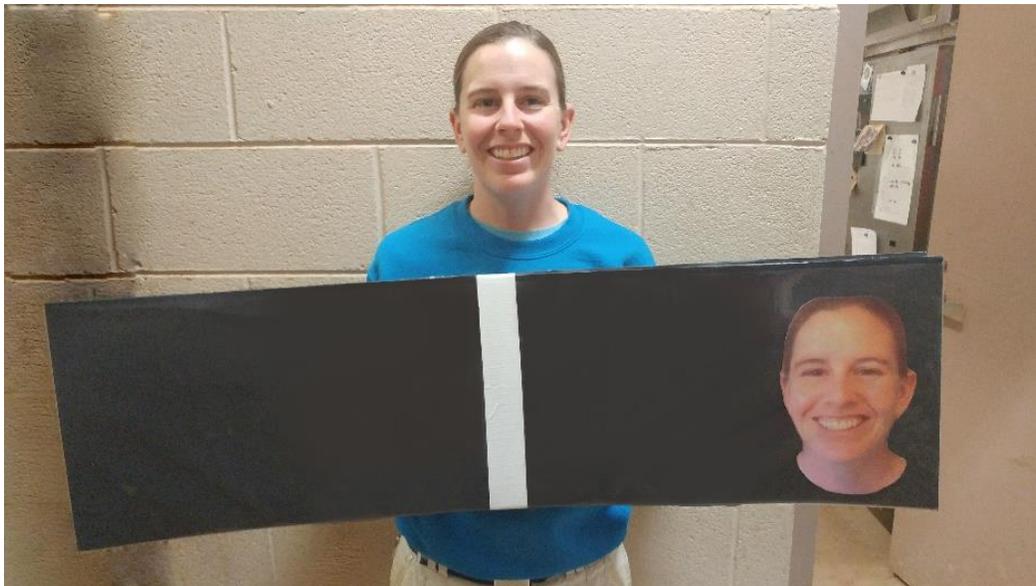
Figure 2.2 Training Phase Set Up

Experiment 1

Materials

Photos of Zoo Knoxville's elephant husbandry staff were taken for human stimulus presentation. All six of the keepers are female and have worked with the elephants for multiple months. Keeper photos were taken against a plain background. All keepers smiled for the photo, wore no glasses on their face or head, and wore no identifying jewelry to ensure elephants were identifying the individual and not matching specific shapes. The photos were printed on 8.5 in. x 11 in. matte photo paper. Photos were trimmed to only consist of the keeper's face and neck and were then be attached to black poster board spanning the length and height of the apparatus (see Figure 2.3). The photos were positioned ½ in. from the left or right and 1 ⅛ in. from either side of the photo apparatus to keep the faces in a constant position across trials.

Figure 2.3 Keeper Photos

Four photo boards were used in each session for experiments 1 and 2. Each board used two photos from a bank consisting of the correct keeper and two alternate keepers. The photo of the correct keeper was on the right for two boards and on the left for two others (see Table 2.1). A keeper only served as the sample for one of the three sessions for each subject. The keeper

used as the sample for each session was decided based on their availability at the time of the session therefore not all keepers served as subjects during experiments 1 and 2.

Table 2.1 Arrangement of Photos on Apparatus

| Board | Position | |
	Left	Right
A	Correct Keeper	Alternate Keeper 1
B	Correct Keeper	Alternate Keeper 2
C	Alternate Keeper 1	Correct Keeper
D	Alternate Keeper 2	Correct Keeper

Procedure

Experiment 1, matching a keeper to one of two photos, was conducted once elephants reached criterion. The apparatus now had two photos (see Table 2.1) and was held by a different keeper in each of three sessions (see Figure 2.4). The elephant saw two photos and was rewarded if they pointed towards the photo of the present keeper with their trunk.

Figure 2.4 Experiment 1 Set Up

To eliminate bias the alternate keeper and location of correct photo were presented in a pseudorandomized sequence with no more than three correct responses on one side (Fellows, 1967) and the keeper was unaware of the position of the correct photo. Keepers were kept unaware of the correct location to prevent any possible cueing of correct response during each trial. The experimenter signaled the keeper of a correct choice with "good" followed by a small food reinforcement and an incorrect choice with "no" with no reinforcement.

Experiment 2

Materials

For the human olfactory component, keepers were given a new white cotton t-shirt that was washed in unscented detergent and placed in a bag. When given the shirt, keepers wore the shirt as they would any other piece of clothing for 24 hrs preceding the session for which their scent served as the sample. They were encouraged to use their same soap, deodorant, perfume, or other products and wear the shirt during their normal daily routine. This was to ensure that their scent would be the smell that the elephants are accustomed to from the keepers. Additionally, as all keepers have worked with the elephants for months, the elephants should be used to any change in smell caused by biological or hormonal changes.

A total of six shirts were worn by keepers, as a freshly worn shirt was needed for each session. Shirts were not used for multiple sessions or between subjects as the shirt lost the person's smell over time and there were likely elephant olfactory cues present after a session. In addition, a keeper only served as the sample for one session per subject. The keeper used as the

sample was decided based on their availability on the day of each session and ability to receive

the shirt before the needed time frame.

Procedure

The procedure was similar to experiment 1, however, the worn t-shirt, rather than the

actual keeper, served as the sample. The head keeper presented the shirt for the subject to smell

at the start and middle of each session. After the initial presentation, the shirt was draped over

the top of the easel. The photo boards for each trial were placed on the easel's ledge (see Figure

2.5). Halfway through the trials, the shirt was presented for smell and rehung before the next

board was shown. Presentation order and reinforcement followed the same procedure as in

experiment 1.

Figure 2.5 Experiment 2 Set Up

Experiment 3

Materials

For the elephant visual sample, human photos were replaced with photos of 2 familiar elephants. Photos were taken of the left and right sides of the three African elephants located at Zoo Knoxville. Photos included the head, ears, trunk, tusks, and face of the elephant. In all photos, elephants had their trunks and ears in a similar position. Photos were printed on 18 in. x 24 in. matte photo paper. Photos were trimmed to remove the background and were then attached to light blue ("sky blue") poster board spanning the length and height of the photo apparatus. The photos of the elephants' right side were positioned ½ in. from the left or right and 1 ⅛ in. from either side of the poster board to keep the photos in a constant position across trials.

For the sample, sample boards were created out of ⅛ in. thick plywood measuring 24 in. x 24 in. and were covered in vinyl. Photos of the left sides of the elephants were attached to light blue poster board and positioned were positioned 2 in. from the bottom and 4 in. from the side of the board. On the back of the boards, two 5 in. long bolts were affixed 4 in. apart on the boards and secured with nuts and a brace. This was set up so that the brace could be placed on the back of the easel and tightened and the board would remain stationary on the top of the easel (see Figure 2.6).

Procedure

Using a similar matching to sample procedure as before, the photo of one side of the familiar elephant was shown to the subject and then attached to the top of the easel. The photo boards with familiar elephants were placed on the ledge of the easel. Photos on each board only

consisted of the two familiar elephants and were never of the elephant serving as the subject due to unknown self-recognition capabilities; it is possible that a photo of themselves would be unfamiliar. Sessions were procedurally conducted in a similar way to sessions in experiment 2; however, instead of the t-shirt being placed over the easel, a sample board was placed on top of the easel. The sample of the familiar elephant remained consistent over trials in sessions 1 and 2 (session 1: familiar elephant A as sample; session 2: familiar elephant B as sample). However, in session 3 the sample photo was changed over trials and was presented in a random and counter-balanced order so that familiar elephant A and B each served as the sample for 20 trials.

Figure 2.6 Experiment 3 Set Up

CHAPTER III

RESULTS

Interrater Reliability

After each session, videos were edited to contain only the trials which occurred. An

ethogram of side choice was then created using Behavioral Observational Research Interactive

Software (BORIS; Friard & Gamba, 2016) and all trials were coded by a blind rater. Cohen's κ

was used to determine the interrater reliability between the blind rater and experimenter. Results

of the analysis found good agreement between raters (κ = .615, $p < .01$).

Experiment 1

Binomial tests with a probability of 0.5 were conducted for each session and overall. As

seen in Table 3.1, Tonka never performed significantly above chance levels during any session

or in the overall experiment. Edie's performance in session 2 and in the overall experiment were

significantly greater than chance.

Table 3.1 Binomial Test Results of Correct Responses in Experiment 1 for Both Subjects

Subject	Session 1		Session 2		Session 3		Experiment 1	
	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.
Tonka	.45	.636	.48	.875	.43	.430	.45	.315
Edie	.60	.268	.75	.002**	.48	.875	.61	.022*

Note. * = $p < .05$; ** = $p < .01$

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Experiment 2

Binomial tests with a probability of 0.5 were conducted for all sessions and for the overall experiment to determine if either subject chose the correct response at significantly greater than chance levels. Tonka never performed at significantly greater than chance levels in any session or overall. Edie performed significantly above chance level in session 1(Table 3.2).

Table 3.2 Binomial Test Results of Correct Responses in Experiment 2 for Both Subjects

	Session 1		Session 2		Session 3		Experiment 2	
Subject	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.
Tonka	.60	.268	.45	.636	.55	.636	.53	.523
Edie	.68	.038*	.48	.875	.60	.268	.58	.082

Note. $* = p < .05$

Experiment 3

Tonka never performed significantly above chance levels (Table 3.3). Edie did not complete experiment 3 as keepers believed she was showing signs of frustration. She completed session 1 and 26 trails in session 2. She did not perform significantly above chance in either session or in all completed trials (Table 3.3).

Table 3.3 Binomial Test Results of Correct Responses in Experiment 3 for Both Subjects

	Session 1		Session 2		Session 3		Experiment 3	
Subject	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.
Tonka	.55	.636	.50	1.00	.60	.268	.55	.315
Edie	.53	.875	.58	.557	-	-	.55	.539

Split Session Analysis

        To determine if any learning occurred during sessions or experiments, sessions were broken into the first and last 20 trials and experiments into the first and last 60 trials and analyzed. As an exception, experiment 3 session 2 for Edie analyzed the first and last 13 trials and for experiment 3 overall, the first and last 33 trials. For this analysis, chi-squared goodness-of-fit tests were conducted to compare each half of the sessions for each subject to determine if the amount of correct responses differed significantly from the first to second half. Results show that there was no significant difference in any session or experiment for either subject (see Table 3.4 and Table 3.5).

Side Bias

        Binomial tests were conducted to determine if a subject exhibited a side bias during sessions or experiments. Data were recoded in this analysis from correct or incorrect choice to the side the subject pointed towards. Results of the analysis show that Tonka exhibited a right-side bias in all sessions and experiments except experiment 1 session 1 where a left side bias was shown. Edie exhibited a side bias in all sessions except in experiment 1 sessions 1 and 3 (Table 3.6).

Table 3.4 Split Session Analysis Results for Tonka

	Experiment 1											
	Session 1				Session 2				Session 3			
	Response				Response				Response			
Session Half	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.
First	7	13	1.616	.204	8	12	.902	.342	8	12	.102	.749
Second	11	9			11	9			9	11		
	Experiment 2											
	Session 1				Session 2				Session 3			
	Response				Response				Response			
Session Half	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.
First	14	6	1.667	.197	8	12	.404	.525	11	9	.000	1
Second	10	10			10	10			11	9		
	Experiment 3											
	Session 1				Session 2				Session 3			
	Response				Response				Response			
Session Half	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.
First	12	8	.404	.525	10	10	.000	1	10	10	1.667	.197
Second	10	10			10	10			14	6		

Table 3.5 Split Session Analysis Results for Edie

	Experiment 1											
	Session 1				Session 2				Session 3			
	Response				Response				Response			
Session Half	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.
First	9	11	3.750	.053	16	4	.533	.465	12	8	2.506	.113
Second	15	5			14	6			7	13		
	Experiment 2											
	Session 1				Session 2				Session 3			
	Response				Response				Response			
Session Half	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.
First	14	6	.114	.736	10	10	.100	.752	13	7	.417	.519
Second	13	7			9	11			11	9		
	Experiment 3											
	Session 1				Session 2				Session 3			
	Response				Response				Response			
Session Half	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.	Correct	Incorrect	χ^2	Sig.
First	12	8	.902	.342	9	4	1.418	.234	–	–	–	–
Second	9	11			6	7			–	–		

Table 3.6 Binomial Test Results of Right Side Choice in All Sessions for Both Subjects

	Experiment 1					
	Session 1		Session 2		Session 3	
Subjects	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.
Tonka	0.3	.017*	0.98	.000**	0.9	.000**
Edie	0.6	.268	0.73	.006**	0.63	.154

	Experiment 2					
	Session 1		Session 2		Session 3	
Subjects	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.
Tonka	0.9	.000**	0.95	.000**	0.88	.000**
Edie	0.73	.006*	0.93	.000**	0.8	.000**

	Experiment 3					
	Session 1		Session 2		Session 3	
Subjects	Obs.	Sig.	Obs.	Sig.	Obs.	Sig.
Tonka	0.68	.038*	1	.000**	0.9	.000**
Edie	0.73	.006**	0.77	.009**	–	–

Note. $* = p < .05$; $** = p < .01$

CHAPTER IV

DISCUSSION

My research provides evidence that African elephants may be capable of visual and

olfactory recognition of individual humans. Edie showed that she may be capable of identifying

familiar humans using visual and olfactory cues. More evidence for this claim is that the keeper

she identified at significantly greater than chance levels in experiment 1 session 2 and

experiment 2 session 1 were different individuals. This means that she may be able to form

representations of multiple familiar individuals. My hypothesis that subjects could visually

recognize familiar elephants was not supported.

The lack of significant results may have been due to a side bias. Analyses showed that

both subjects exhibited a right-side bias during most sessions. As they mostly picked the right-

side photo and were rewarded for that response when correct, they may have not had the proper

motivation to select the correct response as they would still receive food half of the time for a

right-side choice. This side-bias may have also been due to the location of the apparatus as it

remained stationary while subjects frequently moved between and during trials. It may have been

that the right-side of the apparatus was primarily in the view or easier to point to. Future research

may consider moving the apparatus to be centered with the subject or bringing the subject to

center for each trial.

No difference in accuracy between the first and second half of sessions implies that the

elephants were not becoming fatigued during sessions which may have caused a decline in their

performance. Since there was also no increase in performance found during sessions, subjects were not learning the correct response over time. This supports the idea that subjects were not simply learning to match similar shapes during visual recognition experiments. Instead, Edie may have visual and olfactory representations of familiar humans and that those representations were not learned over 40 trials.

Previous research found that African elephants can discriminate between groups of threatening and non-threating humans (Bates et al., 2007; McComb et al., 2014). Current results suggest that Edie is capable of recognizing familiar individual humans. Although similar results were not found with Tonka, it is possible that other elephants may be capable of this ability as well.

It is possible that Edie was simply matching the familiar shape of the face of the keeper holding the board to the similar shape of one of the photos. Her performance during experiment 1 session 2 and overall significant performance may indicate that she was matching features of the keeper holding the board to the photos. If this is the case, her performance may show evidence of picture-object recognition at a perceptual level as she viewed a real person and potentially transferred those shapes to a picture (Watanabe & Aust, 2017). However, Edie also performed significantly greater than chance during an olfactory recognition session. This performance shows she may be capable of forming representations of her keepers and that she can recognize them across sensory modalities.

Little previous research has examined elephants' visual recognition capabilities of other elephants. I was unable to add to this body of research due to a lack of significant results in experiment 3. This may have been due to the exhibited side bias or the design of the study. It may have been that subjects were unable to transfer their visual representations of the other

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elephants due to the photos being substantially smaller than life size; for instance, Tonka is about six times as tall as the photo that was shown to Edie.

Limitations

There are multiple limitations to the current study. First, it is difficult to draw conclusions from the current sample size of 2. Had there been more subjects, it would have been possible to form stronger interpretations and implications from the study's results. Additionally, because there were only three elephants located at Zoo Knoxville and the male is kept separate from the females, this may have interfered with Tonka's ability to correctly recognize either female as well as Edie's ability to recognize Tonka. The separation may lead to less time per day when they are visible to each other which may hinder their ability to form visual representations.

During experiment 2, multiple odors were present in the testing area throughout all sessions. The head keeper remained at least 6 ft. from the subject during sessions and extended the olfactory sample towards them before placing it on top of the easel. The smell of the head keeper and other smells present in the barn may have interfered with the sample scent. Since elephants can determine the direction of a smell by using their trunk as a periscope, it is likely that with the sample being placed on top of the easel and the trunk being pointed towards the easel that the sample scent was the strongest scent observed by the subject (Rasmussen, 2006).

The size of the apparatus in experiment 3 may be considered a limitation. As the pictures were far smaller than an actual elephant, this may interfere with an elephant's ability to recognize the familiar elephant. When Coulon et al. (2011) tested cattle with photos of familiar or unfamiliar conspecifics, the pictures were approximately the size of real cattle faces. Similar results may have been found in the current study used pictures that were true to the elephants'

sizes. Future research should attempt to find additional methods to increase the size of the photos presented while maintaining the ease of switching photo boards between trials to address this limitation.

Third, due to time limitations imposed by the zoo schedule, the initial training phase in this study was concluded before Edie's performance was significantly above chance. Should future research account for the necessary time needed to have all subjects reach significantly above chance performance in the training phase, better performance may be seen throughout the experiments. A training phase before beginning experiment 3 may have also been helpful. While the initial phase seemed to carry through in experiments 1 and 2, performance may have been enhanced in experiment 3 by first training elephants to view and point towards a photo of an elephant. This would have been difficult given the current sample size, however, as showing a subject a photo of a familiar elephant would train them to touch one of the options on the board during the experiment. Also, as they have minimal exposure to a mirror and self-recognition capabilities are unknown in these subjects, training them to view and point towards a photo of themselves may be counterintuitive as this could be considered an unfamiliar elephant.

Future Research

Elephants can determine information about other elephants through olfactory information; therefore future research should examine elephants' olfactory recognition of other elephants (Bates et al., 2008; Rasmussen et al., 2003). Currently there is a fourth experiment planned with Tonka as the subject to assess his olfactory recognition of familiar elephants. This experiment is similar to experiment 2 but the olfactory sample will be the urine of a familiar elephant. The same photo boards and similar session procedures as experiment 3 will be utilized.

Tonka will provide evidence of olfactory recognition of familiar elephants if he performs at significantly greater than chance levels in any session or overall.

Conclusions

Inter- and intraspecific discrimination and recognition have been shown in many species including African elephants. My research provides evidence that African elephants may be capable of visual and olfactory recognition of individual familiar humans. Edie's significantly greater than chance performance in a session of experiment 1 and 2 as well as overall significant performance in experiment 1 show the capability of an African elephant to form representations of humans across different sensory modalities.

My study provides results which add to the current literature on African elephant cognitive abilities. Additionally, knowledge of recognition capabilities can be helpful for social organization of elephant herds by aiding in understanding of how they can recognize individual members. My research is also important for conservation, especially concerning human elephant conflict. Knowing that elephants can recognize individual humans as well as discriminate between groups of humans could be beneficial to find ways to decrease conflict. Individual human recognition is also important in captivity as this may help in the formation of elephant and keeper bonds. By knowing which keepers an elephant can recognize may be beneficial for training purposes. Future research could aim to examine possible connections between recognition abilities and the relationship between the elephant and keepers. However, my study provides initial evidence that elephants are capable of visual and olfactory recognition of individual humans.

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VITA

Victoria Perret was born in Stone Mountain, GA and is the oldest of three, with one brother, Kendall Warren, and one sister, Leslie Kate Warren. Raised by her grandmother, Patricia Perret, she attended Our Lady of the Assumption Elementary and Middle school and St. Pius X Catholic High School. After high school, she attended Georgia College & State University where she earned a Bachelor of Science in Psychology. During this time, she became involved in research with Dr. Diana Young, who inspired her passion for research. After finishing her undergraduate studies, she worked in a child clinical psychology practice under the guidance of Mary Grace Thomas, Ph.D., P.C. and substituted at a local school while being mentored by Susan Pernett. She then attended the University of Tennessee at Chattanooga for a Master of Science degree in Research Psychology. After graduating, she will continue teaching at the college level while working towards acceptance into a comparative psychology Ph.D. program.