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Responses to Mirrors in Domestic Goats (*Capra aegagrus hircus*): Assessing Mirror Use to Solve a Problem and in Self-Recognition

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Master in Biology

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Silje K. Hals

Abstract

Mirror studies in animals have been used to test for self-recognition and instrumental use of the mirror as a tool to find an object hidden from view but visible via mirror-reflection. These abilities have been indicated in several mammalian species and a few bird species, but there are no published mirror studies of goats (*Capra aegagrus hircus*).

The aim of this study was to test for instrumental mirror use in goats, and to observe the goats' reactions towards the mirror to see if they would pass a mark test. A total of 27 subjects were included in the study. Over a 4 day period, the goats were given exposures to a mirror, and each goat was used as its own control, using a window as the control for the mirror. The first 3 days served as a learning phase with 3-4 exposures each day. For the first eight exposures the goats were in pairs, and the last two they did individually, as in the final tests. The mirror was placed in different sections of the experimental setup, and a bucket with treats was placed in front of, or behind, the mirror or the window. On day 4 there were 5 mirror (M) and window (W) tests in the order MMWWM, alternating left and right, and no treats were in the bucket. The sixth test was a Mark test, where a ribbon on a hairclip was attached to the goat's beard while the goat was occupied with eating and its head was inside the bucket. Observations were made with a covered mirror, and then with the mirror exposed, to see if the goat would attempt to remove the mark before or after.

Of the 25 subjects included in the final tests of locating the bucket, no one passed all five tests, but one individual passed four tests by crossing the correct line on the first try. However, the experimental setup enabled for the second and third mirror tests to be passed by location memory, regardless of whether it was set up to the left or right, so further research should adjust the experimental setup to control for this effect. None of the 20 goats in the mark test attempted to remove the mark. The goats' interest in the mirror however, surpassed that of dogs, as they spent much time investigating by looking into the mirror, looking at each other in the mirror, or checking behind the mirror.

In conclusion, the findings of this study were not able to confirm self-recognition in mirrors by goats, or the ability to use the mirror as a tool to solve a problem. Further adjustments could be made to test for instrumental mirror use in goats in future studies, by allowing more time with mirrors and problem-solving training prior to the testing phase.

Sammendrag

Speilforsøk hos dyr har blitt brukt for å teste om de kan kjenne igjen seg selv i et speilbilde, eller om de kan bruke speilet som et verktøy for å lokalisere et skjult objekt som ikke er synlig for det blotte øyet, men som kan sees i speil-refleksjonen. Disse egenskapene er blitt påvist hos flere arter av pattedyr og hos noen fuglearter, men det er ikke blitt utgitt noen studier på speilforsøk hos geiter. Målet med denne studien var å teste instrumentalt bruk av speil hos geiter, samt å observere geitenes reaksjoner til speilet for å se om de klarte testen med å fjerne merket de hadde festet i skjegget sitt.

Totalt 27 geiter var inkludert i denne studien. Over en 4-dagers periode, ble geitene gitt tilgang til et speil, og hver geit ble brukt som sin egen kontroll ved bruk av et vindu som fungerte som kontroll for speilet. De første 3 dagene fungerte som en læringsfase med 3-4 sesjoner hver dag. De første åtte sesjonene var geitene i par, mens de siste to samt testene på dag 4 ble gjennomført individuelt. Speilet var plassert forskjellige steder i test-båsen med det eksperimentelle oppsettet, og en bøtte med godbiter oppi var plassert enten foran eller bak speilet eller vinduet. På dag 4 ble det gjennomført 5 speil (S) og vindu (V) tester i rekkefølgen SSVVS, både til høyre og venstre, og uten godbiter i bøtta. Den sjetteste testen var en 'Mark test', og en sløyfe på en liten hårklips ble festet til geitens skjegg mens den var opptatt med å spise med hodet nedi bøtta. Det ble gjort observasjoner med speilet dekket, og deretter med speilet synlig, for å se om geiten ville forsøke å fjerne sløyfa fra skjegget før eller etter den kunne se i speilbildet.

Av de 25 geitene som deltok på testene den siste dagen med å lokalisere bøtta, var det ingen som klarte alle fem testene, men én geit klarte fire tester ved å krysse den korrekte linjen på første forsøk. Det var likevel et minus ved det eksperimentelle oppsettet slik at i andre og tredje speiltest var det mulig å velge korrekt sted ut fra hukommelse om hvor bøtta var i forrige speilforsøk, uavhengig av om den var til høyre eller venstre, så videre speil-studier burde justere oppsettet for å kontrollere for denne effekten. Ingen av de 20 geitene som deltok i 'Mark test'en forsøkte å fjerne sløyfa. Geitenes interesse for speilet var derimot meget høy, og overgikk den interessen som er typisk for hunder. De brukte mye tid på å undersøke speilet ved å se i speilet, se på den andre geita i speilbildet, og gå bak speilet for å sjekke.

Konklusjonen i denne studien er at det ikke kunne påvises hverken at geitene kjente igjen seg selv i speilbildet, eller at de klarte å bruke speilet som verktøy for å løse et problem. For videre studier av geiter og speil kan man gjøre justeringer for å teste instrumental bruk av speil, ved å gi geitene mer tid med speil og mer problemløsnings-trening i forkant av testfasen.

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1. INTRODUCTION

1.1. Goats

1.1.1. Domestication, natural behavior & physical attributes

The domestic goat (*Capra aegagrus hircus*) was one of the first species of animals to be domesticated, previously estimated to have taken place 8000 -12 000 years ago, about the same time as sheep (Ekesbo, 2011), but recent molecular findings in goat genes could indicate an earlier domestication up to almost 100,000 years ago, although it is not clear if the population expansions were due to domestication (Nomura, Yonezawa, Mano, Kawakami, Shedlock, Hasegawa & Amano, 2013). These animals were practical to domesticate because of their social systems which made them relatively easy to herd. Although sheep have been researched more, goats are very tough animals who adapt easily to harsh environments. Goats are social animals and live in herds in a natural environment with a strong hierarchical system, but unlike sheep who graze and stay close together as a herd, goats are more versatile eaters. Goats are opportunistic browsers who can search for food in places that are hard to reach, such as trees and steep rocky terrains, as they are good climbers (Ekesbo, 2011), with good spatial awareness. They seek more inter-species distance than sheep (Chojnacki, 2014). Within the flock, they communicate in visual, olfactory and acoustic modalities, and if separated from the flock they become more vocal (Rutter, 2002). Although they have a strong desire to be with their flock, there can be adverse effects if being regrouped with new goats (Patt, Gygax, Wechsler, Hillmann, Palme & Keil, 2013).

Goats have good hearing (60 – 40,000 Hz), and react towards high or unexpected sounds. Their olfactory sense is well-developed and used for identification of conspecifics and possible sources of food. Scent glands are placed on feet and under the tail, and goats often sniff each other, including mothers for recognizing kids. Eye sight is excellent with a panoramic field of vision (320-340°, binocular vision 20-60°), and testing has shown goats to distinguish the following colors from similar shades of grey: Blue, violet, green, yellow and orange (Ekesbo, 2011).

Grooming is not as prevalent as in birds, whose feathers are needed for flying and survival (Prior, Schwarz & Gunturkun, 2008), but goats do try to keep their hair clean to protect them from cold weather (Ekesbo, 2011).

Goats spend much time exploring new environments when left undisturbed. The

natural problem solving skills of goats have been observed in goat farming where goats have managed to open latches on gates, and investigate new areas and passages (Ekesbo, 2011).

1.1.2. Goat cognition

Domestication of goats has led to selection for a larger body size (80 kg average, versus 45 kg for wild goats; *Capra aegagrus*), and the brain mass of domestic goats is smaller (0.13 kg) than in wild goats (0.18 kg), yet domestic goats have performed relatively well in some cognitive studies (Briefer et al., 2014). Goats are capable of solving complex two-step tasks and have long-term memory, as demonstrated in a study by Briefer et al (2014), where the goats were trained and learned the task within 12 trials on average, and when tested again up to 10 months later, they spent less than two minutes solving the task. The study also indicates that the goats learned individually, as they did not learn faster from social learning with a demonstrator. Another study also found that goats preferred personal over social information when both were options (Baciadonna, McElligott & Briefer, 2013).

The basic social cognitive skill of gaze following, which is beneficial for animals living in groups, was found in a study of goats, who were able to find food by following the gaze direction of a conspecific. The goats were able to use human cues of pointing and touching, but not human gaze direction. Dogs are skilled at human cues, unlike wolves, so goats attending to human cues could possibly be a side-effect of domestication (Kaminsky, Riedel, Call & Tomasello, 2005). In a recent study, the goats used a human's head as cue, but also here did not use cues from human eyes, and the authors theorize that it could be due to the differences in morphological traits of the eyes, where goats' eyes do not have the same ability to show gaze direction as human eyes do, and that when using cues from conspecifics gaze direction, it could possibly rather be by head direction (Nawroth, von Borell & Langbein, 2016).

An object permanence ability study of goat kids showed that even at an early age of 6 weeks, goat kids have cognitive skills that are considered advanced (Chojnacki, 2014). Goats seem to seek challenges, and particularly individuals who master one challenge will more often seek out a new challenge, even when it's not necessary because the reward is easily accessible in another place (Langbein, Siebert & Nürnberg, 2009), making them ideal candidates for mirror-studies.

1.2. Mirror studies

Mirror studies with human infants and children, as well as a few animal species, have been used as a method to test for cognitive abilities such as self-awareness and problem-solving. In the 1970s, Gallup reasoned that self-recognition in mirrors implied self-awareness, which implies Theory of Mind, meaning that an individual can apply what they know from understanding their own mind, to reason how the mind of another individual must work. Human children is thought to develop Theory of Mind at the age of 4, and self-recognition in mirrors when they are about two years old, according to most developmental psychologists (Swartz, 2003).

Self-awareness in humans has been categorized in five levels of development between birth and 4-5 years of age based on reactions to mirror reflections. Level 0 (confusion) is no understanding of the reflection, and what is seen in the mirror is perceived as the environment or another individual, and aggression in animals can occur. Level 1 (differentiation) is understanding that there is a reflection. Level 2 (situation) is exploration when the individual understands that its own body movements correspond with what is seen in the mirror reflection. Level 3 (identification) is when the realization of a “Me” occurs, and when a mark on the individuals forehead is removed. Level 4 (permanence) is recognizing the self in photos from the past, even if the appearance have changed. Level 5 (self-consciousness or “meta” self-awareness) is thinking of oneself in third person, as perceived by others. Human infants are thought to be born with the level 1 awareness, and reach level 2 from the age of 2 months (Rochat, 2003).

Instrumental mirror use is problem-solving with the use of a mirror. The target is often food that is hidden from plain sight, but visible via mirror-reflection, and subjects are observed to see whether they will go towards (or if possible behind the mirror), or to the location where the target is actually placed. Instrumental mirror use has been found in Chimpanzees (*Pan troglodytes*), different species of monkeys, elephants (*Elepahs maximus*), parrots (*Psittacus erithacus*) and crows (*Corvus macrorhynchos*). Dogs (*Canis familiaris*) have generally not performed well in mirror-tests (Gielsing, Mijdam, van der Staay & Nordquist, 2014). Many dogs, like humans, grow up surrounded by mirrors in their homes. One mirror study of dogs mention that 2-7 dogs possibly understood the reflection and that dogs might be able to learn about the function of mirror (Howell & Bennett, 2011). Another study concluded with the dogs' ability to use the mirror to find hidden food through visual cues, but they were unable to control for possible uses of scent cues (Howell, Toukhsati, Conduit & Bennett, 2013). Instrumental mirror use in pigs (*Sus scrofa*) was indicated in a

mirror-study with seven out of eight mirror experienced piglets locating food that was hidden behind a barrier (Broom, Sena & Moynihan, 2009), but a follow up study that aimed to closely replicate this study did not find the same positive results (Gielsing et al., 2014).

Mirror self-recognition (MSR) is rare in animals, and is often determined by a "mark test", when a marking is placed somewhere on the body and can only be seen in the mirror reflection. Leading up to a mark-test, stages of behaviors that can be seen in MSR are: social responses, physical inspection (such as looking behind the mirror), repetitive mirrortesting behavior, and realization of seeing themselves (Plotnik, de Waal & Reiss, 2006).

Chimpanzees were the subjects of the first marktest in 1970, anesthetized to be marked and then exposed to a mirror for 10 days, before passing the mark test, but several species of monkeys did not pass the test (Gallup, 1977). Several studies in later years have come up with the same negative results for monkeys (Paukner, Anderson & Fujita, 2004; (Roma, Silberberg, Huntsberry, Christensen, Ruggiero & Suomi, 2007), although one study argues to the contrary that capuchin monkeys (*Cebus apella*) recognizes the difference between their own reflection in the mirror and another conspecific, or possibly somewhere inbetween (de Waal, Dindo, Freeman & Hall, 2005).

Animals other than chimpanzees that have passed a mark test are: elephants, dolphins (*Tursiops truncatus*), and mag pies (*Pica pica*) (Gielsing et al., 2014). Killer whales (*Orcinus orca*) and false killer whales (*Pseudorca crassidens*) also seem to share the cognitive abilities of bottlenose dolphins required for self-recognition (Delfour & Marten, 2001).

However, not all subjects in these tests necessarily pass the test. Only about one third of the 92 chimpanzees showed signs of self-exploration (21 subjects with clear and 9 with weak evidence), and about half of the 21 passed the mark test (Povinelli, Gallup, Eddy, Bierschwale, Engstrom, Perilloux & Toxopeus, 1997). In a study of Asian elephants, only one of three subjects passed the mark test (Plotnik et al., 2006). In the mag pie mirror study, there were only 5 subjects, but evidence of mark-directed behavior was observed in 3 individuals (Prior, Schwarz & Gunturkun, 2008).

There have been raised questions around the mark test as evidence of self-recognition, because it could also be an a kinesthetic imitation, which has been observed in infants watching a person with a mark (Mitchell, 1993). Video tests have been used for monkey species and is a recommended method to test species that don't pass mirror-tests of self-recognition (Anderson, Kuroshima, Paukner & Fujita, 2009).

Technical methods such as neural imaging has identified areas in the human brain involved in perceptions, but this is difficult to apply to animals due to restriction (Bekoff &

Sherman, 2004). Dogs brains have recently been successfully scanned in an MRI scanner, but this is still a new area of study for animals other than humans and primates, and it requires training and voluntary participation for best results (Berns, Brooks & Spivak, 2012). For now, mirror studies can serve as a practical and managable method to conduct studies that can point to self-awareness in animals.

To my knowledge, no mirror studies in goats have been published.

1.3. Why mirror studies in goats is relevant

In nature, goats have to use their cognitive skills in food foraging, or when faced with predators, for survival (Meehan & Mench, 2007), whereas in a domesticated environment the food is provided and natural dangers limited. Especially in the winters, when the dairy goats spend much time indoors, cognitive challenges for goats in their daily housing could produce positive feelings of achievement and a certain degree of control over the environment, which benefits the well-being of the animals (Langbein et al. 2009).

1.4. Background (Previous goat study)

As part of a group project in the Ethological Methods class HET300 at the Norwegian University of Life Sciences, I conducted a mirror-study on goats together with another student, and we based the experimental design on the two mirror-studies on piglets (Broom, Sena & Moynihan, 2009; Gieling et al. 2014), but made a few alterations. We used 16 goats, of which 8 were mirror exposed (ME) and 8 were mirror naive (MN) to serve as a control group. The ME goats were exposed to a mirror for 15 minutes on the first day in groups of four, 6 minutes on the second day in pairs, and 3 minutes alone on the third day. The control group (MN) did the same but with the mirror covered with a blanket. Day 1 was only with mirror, but on the 2nd and 3rd day, there was a bucket with treats in front of the mirrors. On the test day, both ME and MN goats had 3 tests alone, and each test was ended when the goat found the bucket. To control for scent as a cue to find the bucket, there were no treats in the bucket on the test day, but when the goats found the bucket, they were given treats from another identical bucket that was brought to them, to keep them motivated throughout the three tests. The first test was with a mirror (and option was to go behind the mirror-barrier, or the side-barrier, so a 50-50 chance setup), then with a control for the mirror being a hole through the barrier, and finally in the third test with a mirror again. The results from this study revealed that all the goats showed a great deal of interest in the mirror, but no one passed the

final mirror-test on day 4.

1.5. Current mirror study

In this study, I wanted to give the goats more learning opportunities with a hidden bucket in relation to the mirror, with a larger group size exposed to the mirror, so instead of having a control-group, each animal served as its own control and I used a window as the control for the mirror. Instead of a 50-50 chance in the mirror-test, I designed a new experimental setup with several barriers and a left/right option, making it a 1/3 chance of looking the correct place for the bucket in the final tests. The number of final tests was increased to a total of 5 tests, with two mirror-tests, two control-tests, and a final mirror-test.

The aim of this study was to find out if goats are able to grasp the concept of the mirror well enough to use the mirror as a tool to find a hidden object, and/or show self-awareness by attempting to remove a mark attached onto themselves.

For the instrumental mirror-test, the following research questions were asked:

- 1) Were the goats able to use the mirror to solve a problem (find hidden bucket) on Day 4?
- 2) Did goats with greater historical experience with the mirror (ME) find the bucket faster than goats with less experience (MN) or (New) on Day 4 or Days 1-3?
- 3) Did ME goats have more successes in finding the bucket than MN or New goats on Day 4 or Days 1-3?
- 4) Did age influence ability to find bucket faster or more often on Day 4 or Days 1-3?
- 5) Did the goats who scored higher on mirror (or window) variables from Days 1-3 do better in mirror (or window) trials on Day 4 than goats with lower scores?
- 6) Did the goats investigate the mirror on Days 1-3 by looking at or behind the mirror more often and for longer than they looked at the window (control)?
- 7) Did the goats who reached the bucket first more often or faster on Days 1-3 also do better in trials (finding bucket, finding bucket faster, crossing the correct line on first try and choosing to look the correct place vs finding it by mistake) on Day 4?

The research question asked for the mark-test:

- Were the goats able to remove the mark as a result of recognizing themselves in the mirror?

2. METHODS & MATERIALS

2.1. Subjects

The subjects of this study were 27 female Norwegian dairy goats, ranging from 1-6 years of age, and part of the experimental herd at the Norwegian University of Life Sciences (see Table 1). The goats were identified by individual ID numbers on ear tags (Goat ID#).

Originally there were 24 goats in 12 couples, but another pair got added on the second day of week 1 that turned out to be available after all (GoatID 1548 and 3121), and 1 goat got sick (GoatID 40) and had to be replaced by another goat (GoatID 2121) on Day 3 of week 1, so since the data for those goats were included in some of the results from days 1-3, the total number of goats included ended up being 27.

Most of the goats were pregnant in the last trimester, and therefore the initial selection of individuals to participate in the study was based on which goats were available in the time period. The subjects were chosen based on expected time of parturition, so they would be done with the project several days prior to labor. The reasons for this decision, was to avoid the stress of separating mothers from their young for many hours, and to make it equal for all subjects who participated (that no one had yet given birth), so their focus could be on the mirror and bucket. The goat herd was scheduled to be moved permanently to a new facility a few kilometers away, on March 15, 2015, so this project had a time limit of 3-4 weeks in which it had to be conducted.

Seven of the goats had previously participated in a mirror-project four months prior to this study. Of those, four were *mirror exposed* goats (*ME*) and 3 *mirror naive* goats (*MN*). The remaining 20 goats had never seen a mirror before, and were exposed to mirrors for the first time in this project (*New*). These new goats were selected after a pre-screening session to find out which individuals would be the most appropriate for this study. The main criteria were curiosity and lack of fear. A teddy-doll was first covered in pellets, so it would carry the scent of food. It was placed on the concrete floor in the hallway of the main goat house, and lines were drawn on the floor in front of it (1 meter mark, 2 meters, and the doll was at the 3 meter mark), as I wanted to see how close to the doll each goat dared to go (see Figure A.1 in the Appendix). I noted down how many seconds the goats spent by the doll investigating it and sniffing it. Notes were also made on whether each goat followed me easily, or refused to come and ran away from me. The goats that were chosen were the most curious about the doll, and were easy-going versus anxious/fearful.

Three groups were established, based on expected labor dates, Week 1 (n=12), Week 2 (n=6) and Week 3 (n=8). Day 1 up to Day 4 refers to the number of day with exposures for each group per week. At least two of the days per week were consecutive, with a break of a couple of days in between, before continuing. Training occurred on Days 1-3, followed by testing on Day 4 (see below for explanation of training and testing). In Weeks 1 and 3, the goats in each group were randomly divided into two equal sub-groups. On Day 1, one sub-group was randomly assigned to training in the morning and the other sub-group was trained in the afternoon. The order of training/testing of each sub-group was alternated on subsequent days. Because there was a smaller group in Week 2, all goats were tested in the morning on each day.

Table 1. Subjects in the study.

Goat ID#	Age (in years)	Previous Mirror Experience	Week participated
444	1	New	2
541	1	New	2
448	1	New	2
425	1	New	2
470	1	New	2
3055	2	New	1
3072	2	New	1
3121	2	New	1
3008	2	New	1
3157	2	New	2
33034	2	New	3
3040	2	New	3
2008	3	New	1
2121	3	New	1
2058	3	New	3
2024	3	New	3
11501	4	ME	1
1548	4	ME	1
11505	4	ME	1
11523	4	MN	1
11506	4	MN	1
11578	4	ME	3
1541	4	MN	3
70	5	New	1
40	5	New	1

9153	6	New	3
9202	6	New	3

2.2. Housing & management

The goat house at the Norwegian University of Life Sciences was an old wood building for animal housing, with a fenced outside area that the goats had access to during the day when the door was open. The inside space where the goats were kept, had expanded metal flooring with a 60 cm solid floor section covered with sawdust alongside the wall, for resting. In the middle of the room there was a feeding area separated by two wooden fences with an opening slot for heads to get through. The density of Norwegian goat housing is commonly 0.6 – 0.8 squaremeters per goat during the winter (Bøe, Ehrlenbruch & Andersen, 2012).

This study took place between February 15 – March 15, 2015, and the indoor temperatures at that time of year in the buildings were about 10 degrees Celcius. Artificial lights were switched on/off at 6 am/6 pm.

The goats were fed and milked twice a day. In the morning around 6 am the goats were milked (with a milking machine) and then given baled silage and pellets. They were fed again between 2 – 3 pm with baled silage and some hay, and were milked around 3:30 pm. Water dispensers, salt blocks and grass hay were available to the goats at all times. The area was cleaned twice a day after feeding.

2.3. Apparatus (the set-up)

2.3.1. The building

The building in which the experiment took place, was located about 50 meters from the regular goat house (about 20 meters from the fence of the goats' outdoor section). Part of the building was housing for horses participating in university studies, and part of the building was at the time a temporary housing for sheep. The part of the building used in this study, was at the end section of the building with two big barn doors as entry. The doors lead into a vacant room of approximately 14 x 5 meters. On the immediate left, there was a regular door that lead into the room mainly used in this experiment, which was identical in size as the first room. The second, main room for this experiment, had 3 pens and a hallway (see Fig.1). The "test pen" was the same size as the "waiting pen" and "temporary pen" combined. There was a solid barrier between the test pen and the other two pens. The waiting pen and the temporary

pen were separated, but had a small door between them, and both pens had doors that opened out to the hallway. The concrete floor was covered with a thick layer of sawdust in the pens. Temperature at the time of this study inside the building was around 10 degrees Celcius. There was artificial lighting in the ceiling during the day when the study took place, as well as natural light coming from windows high up alongside the one wall that faced the outside. The goats were accompanied to the building on foot, by following one or two persons with a bucket containing pellets, as they were trained to do. Individuals who would not follow easily were lead by a collar around their neck.

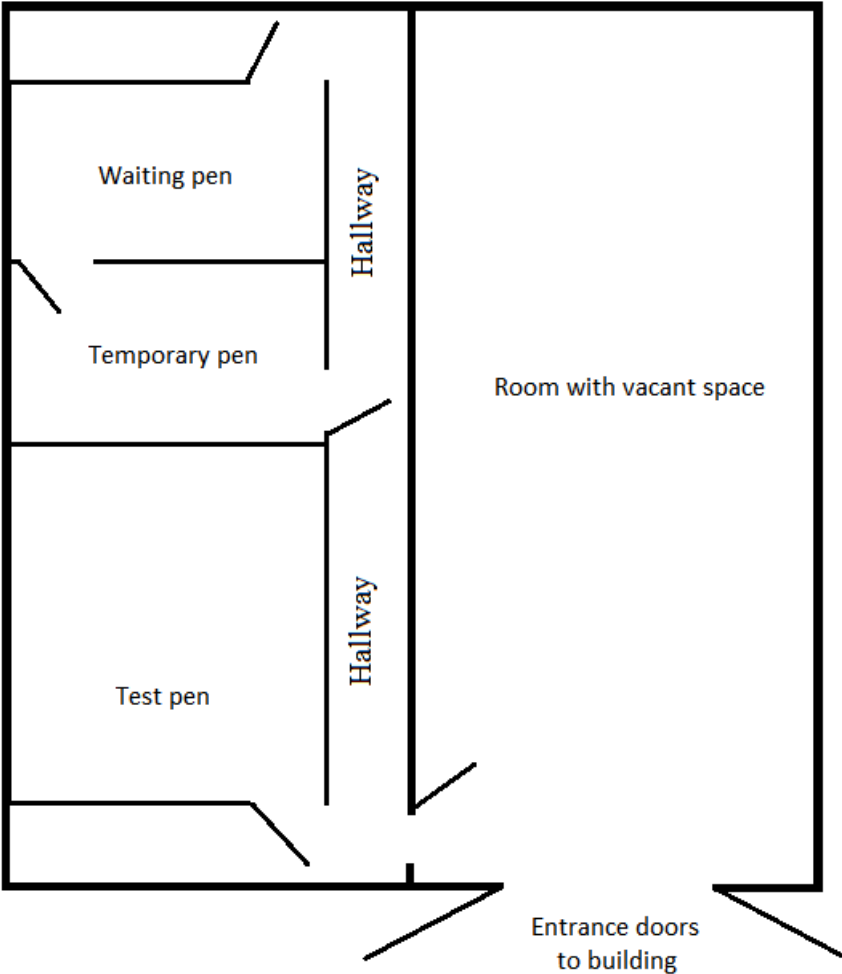


Fig.1. The room where the experiments took place to the left, with the 3 pens used.

2.3.2. The waiting pen

Fresh straw was laid out on the floor, so the goats would have a clean, soft ground to lay down on for rest. Some grass hay and a few pellets were put in the tray every day when the goats were first brought there each day. A bucket of fresh water (which was changed

every day) was securely fastened to one wall. All goats in a group (sub-group per day) were brought to the waiting pen, and then two (or one) goat(s) were taken to the test pen for each session and observed while the other 2-4 goats waited in the waiting pen for their turn.

2.3.3. The temporary pen

This pen was used as an aid when getting out the chosen subjects for each exposure, and when the correct pair of goats were gathered (identified by Goat ID#), they were lead out to the hallway and down to the test pen.

2.3.4. The test pen (*Test arena*)

The pen with the experimental setup was where all of the exposures took place (see Fig.2). There were two front barriers, one on each side against the wall about mid-way in the pen (LFB & RFB), and the imaginary line between them was named "Line 1" (which was used to set the starting point in Latency-measurements, see Table 2). Further in, there were two barriers that formed a "T" to the right, and two barriers to the left. The longest barriers that served as a place to attach a mirror and window (LMWB & RMWB) had both a 133.5 x 38.5 cm hole cut out in the middle, to allow room for the window. This was the same size as the mirror-surface of the mirror (not including the frame around the mirror). In front of these two barriers right in the middle, were two dividing barriers (LBDB & RBDB)

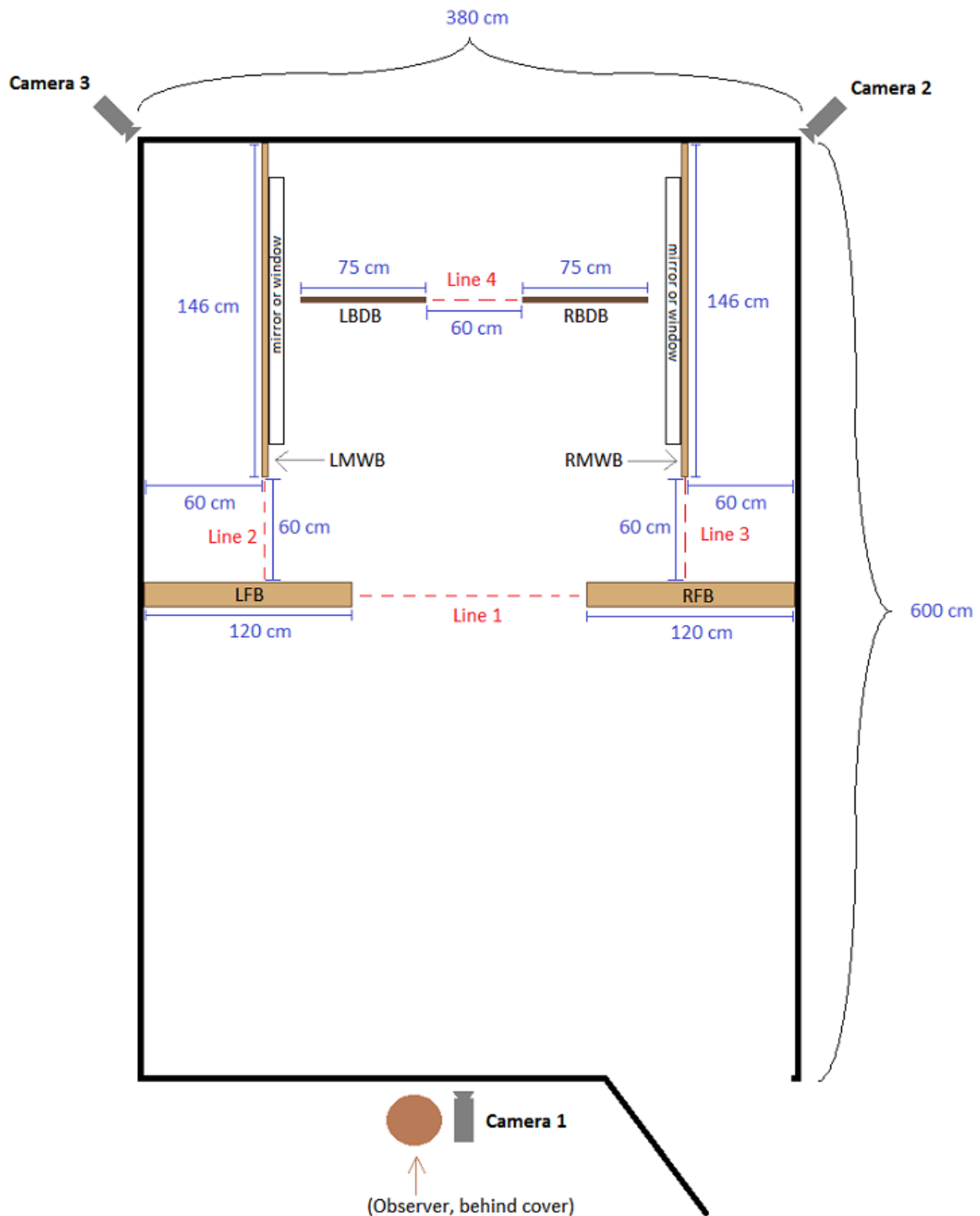


Fig. 2. The experimental set up of the test arena with measurements, positions of cameras, the observer, and the barriers; right back divider barrier (RBDB), left back divider barrier (LBDB), right mirror-window barrier (RMWB), left mirror-window barrier (LMWB), right front barrier (RFB) and left front barrier (LFB). The imaginary lines between the front barriers and mirror/window-barriers were "Line 2" and "Line 3", and the imaginary line between the two back barriers was Line 4 (Line 2, 3 and 4 were the three possible options of

where to find the bucket in the tests on Day 4).

2.3.5. The mirror

The size of the mirror used was 140 x 45 cm, of which the wooden framework was 6.5 cm, so the mirror surface was then 133.5 x 38.5 cm. A plexiglass was attached to the front of the mirror as protection so the mirror could not be shattered, and it was 6 cm out from the mirror (depth?).

2.3.6. The window

The window served as a control for the mirror. The window was a plexiglass with the length of 133.5 cm. A piece of wood was attached to each corner of the window that was used to hold the window in place. It fit exactly into the hole in the barrier, making it the same size as the mirror surface.

2.3.7. The bucket

A smaller sized bucket (approximately 25 cm in diameter and 30 cm tall) was used throughout the experiment, and for the first 3 days there were treats in this bucket so the goats were conditioned to anticipate treats in the bucket on Day 4 as well (although there were no treats in the bucket in the tests on Day 4, see under section 2.4.3.). Two identical buckets were made, as one had to be completely clean and free of food-scents, to be used in the tests on Day 4. The bucket(s) had a design on two opposite sides of the bucket (see Fig.A.2 in Appendix), and a pattern on one half of the upper rim, that I had drawn on with a blue waterproof marker. The thought behind that, was that the image was different from left to right, and that it would be a mirrored image in the mirror, which could serve as an additional guiding element in the process of learning to understand what the mirror image represents.

2.3.8. The "mark" in the mark test

A small hairclip with several colored ribbons served as the "mark", and was attached in the goat's beard (See Fig.A.3 in Appendix). The thought was that this was a good place on the body of a goat to attach something, that would both be easily visible in the mirror-reflection, and that the goat could possibly try to remove it by using its mouth. I assumed that they would ignore spray-paint marks because they were habituated to their presence as a consequence of their use in routine husbandry. Also, a mark on the forehead, which is

commonly used in Mark tests would be a difficult place for goats to reach, as they don't have hands or trunks to use in the same sense.

2.4. Procedure

2.4.1. The experimental design (Days 1-4)

Over a total of 4 days, there were 3 exposures per day on Days 1 and 2, and 4 exposures on Day 3. On Day 4, there were 5 tests with mirror (M) or window (W) in the sequence (MMWWM) and a sixth test which was a Mark test. In the first 3 days, the mirror and bucket were placed in different locations during different exposures. The goats would have to go in all of the sections of the set-up when looking for the bucket, and this was done in order to familiarize the goats with the setup before the final tests, as well as taking area preference into account and balance exploration across different areas of the arena.

The first two exposures on the first day were the same for all the goats in all three weeks. In the very first exposure, the mirror was on the right front barrier (RFB) for all the goats so that they would see the mirror straight ahead immediately when entering the pen (see Fig.3). In the second exposure, the mirror was placed straight ahead in the middle, with the bucket in front (see Fig.3). The rest of the exposures throughout the period (from, and including, the third exposure on Day 1) could be set up either to the LEFT side, or to the RIGHT side, and I alternated between the two options to make it close to half and half. The goats were in pairs for the first 8 exposures, but each goat was observed by video-recordings later, so data was obtained per individual. Since there were 13 pairs altogether, I started the 6 pairs of Week 1 with the LEFT side, and the remaining 7 pairs (with 3 pairs from Week 2, and 4 pairs in Week 3) started with the RIGHT side. Every other exposure was left and right, to adjust for location, so that the goats would not learn to look for the bucket in just one area of the pen. The tests on Day 4 were also split in alternating sides, with half of the goats starting RIGHT and the other half starting LEFT.

For all goats, I also switched around the order within each group when it came to who went first, second or last of the pairs (a pair got bumped up one step in the order for each time, so it rotated through different positions in the sequence).

The mirror and window were wiped clean with a piece of cloth after each exposure, as there was sometimes some moisture from the goats' noses or breaths that made the surface look foggy. If any pieces of treats had fallen on the floor, I removed those before the next session.

All sessions were observed from behind a cover, with only a narrow tinted window, but mainly from viewing the screen of the videocamera placed on a tall pole above the observer. All efforts were made to be out of sight and not be heard by the subjects, in order not to disturb them and minimize effects on results. All sessions were videofilmed with 3 cameras (for positions, see Fig.2).

2.4.2. Training (Days 1 - 3)

The goats were given different exposures to the mirror and window, and with the bucket placed in front or behind the mirror and window, or hidden. The bucket was used as a tool to give them a chance to learn what the mirror and window represented. The window was always placed on either the left or right mirror-window barrier (LMWB or RMWB, see Fig.2). When the mirror was not on the mirror-window barrier opposite from the window, but placed on the floor or on the right front barrier (RFB), there was an empty hole on the other mirror-window barrier opposite from the window.

All exposures were 5 minutes, except three exposures that were 1.5 minutes. The last two exposures of Day 3 when the goats were alone, as well as exposure 1 on Day 3 which was 1.5 minute (the reason for that was that there were 4 exposures that day, and many goats in Week 1, and once the bucket was reached, there was not much point in keeping the exposure long, as the goats had already had 2 days with 6 prior exposures of 5 minutes). However I increased the time again to 5 minutes in the next exposure due to the difficulty/challenge of finding the bucket, which was now placed behind the mirror and not visible until the goats went to look behind the mirror.

Different treats were given for some of the exposures to add a surprise element, and with advisement from the daily goat handler I assumed the goats would appreciate these new treats, which is rare for them to get otherwise (treat type is mentioned for each exposure below).

Day 1

Exposure 1

The mirror was on the right front barrier for all the goats, so it would be seen straight ahead when first entering the bin (see Fig.3). There was no bucket or food in this exposure, because the mirror should be the focus of attention, but an exception was made for the

youngest goats in Week 2 because they ran so quickly to the back so might not have even registered the mirror and seemed a little scared to come back to the front area. So in order to lure them in front of the mirror, a bucket with some food (pellets) was placed on the floor in front of the mirror after 1 minute 50 seconds for all three pairs.

Exposure 2

The mirror was placed on the floor in the middle right in front of the back divider barriers (LBDB & RBDB), and a bucket was placed in front of the mirror, so it was visible in the mirror reflection. Treat type in the bucket was a thin layer of pellets.

Exposure 3

This was the first exposure with a hidden bucket. The mirror was placed as in the previous exposure, but now the bucket was hidden up against the back side of the front barrier, either to the left or the right (behind LFB or RFB) (see Fig. 3). Treat type was pellets again.

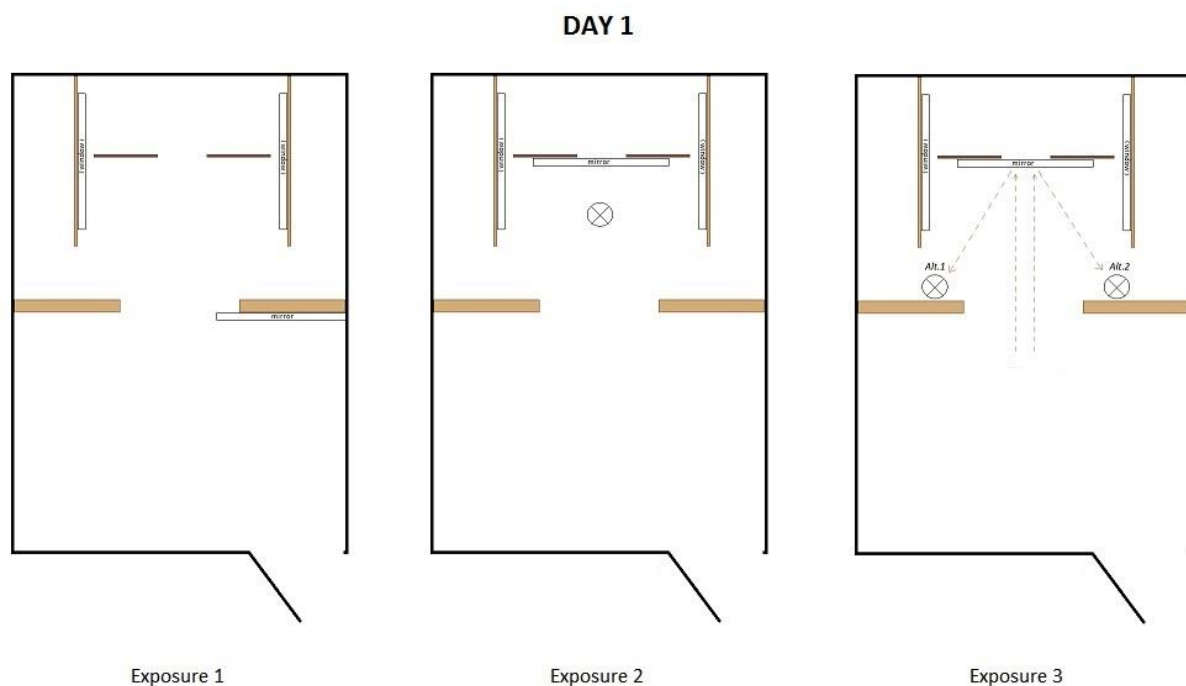


Fig. 3. Day 1 with the 3 exposures, showing where the bucket and mirror was placed. *Exposure 1*) Mirror was on the right front barrier. *Exposure 2*) The mirror was on the floor in front of the two back divider barriers, and the bucket was placed on the floor in front of it.

Exposure 3) The mirror was placed as in previous exposure, but the bucket was now hidden behind one of the front barriers, but visible in the mirror-reflection, and the striped line in beige color shows the lines/angles of visibility for either two alternatives (left or right).

Day 2

Exposure 1

The mirror was on the floor in the middle in the very back and the bucket was hidden behind the back divider barrier, either to the left or the right (LBDB or RBDB) (see Fig. 4.). Treat type in the bucket today was 3 pieces of apple.

Exposure 2

The mirror was up higher, attached to one of the two mirror/window barriers (LMWB or RMWB), and the bucket was placed on a cardboard-box (about 50 cm tall) in front of the mirror, so that the bucket was visible in the mirror-reflection. Treat type in the bucket was 3 pieces of carrot.

Exposure 3

The bucket was in front of the window on the opposite side (if left in previous exposure, then right in this exposure, and vice versa) on top of the cardboard-box. The thought behind this, was to show that there was a difference between the mirror versus the window, as there was a reflection of the bucket when in front of the mirror, but not the same when placed in front of the window. Treat type in the bucket was 3 pieces of pear.

DAY 2

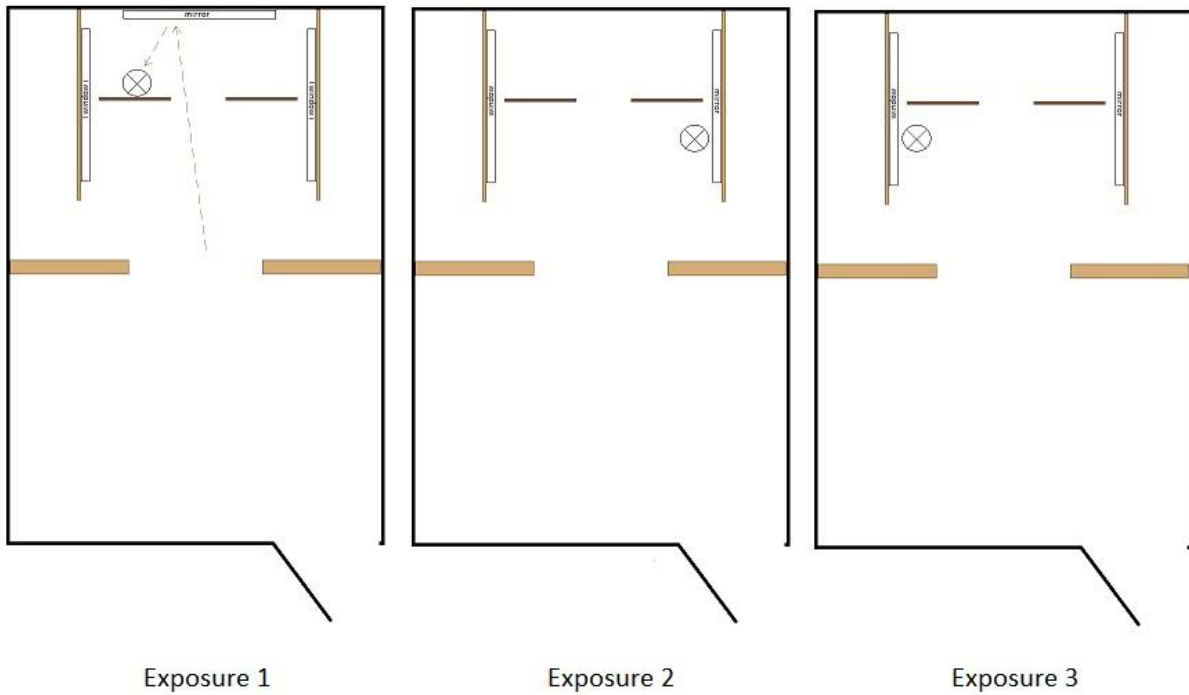


Fig. 4. Day 2 with the 3 exposures, showing where the bucket and mirror was placed. *Exposure 1*) The mirror was in the very back in the middle on the floor, and the bucket was on the floor hidden behind either left or right back divider barrier, but visible in the mirror-reflection. *Exposure 2*) The mirror was on either the left or right mirror-window barrier, and the bucket was on top of a cardboard box in front of the mirror, visible in the mirror-reflection. *Exposure 3*) The bucket was on top of the box in front of the window, on the opposite side as in previous exposure.

Day 3

Exposure 1

The bucket was placed behind the window (see Fig. 5.) on top of the cardboard-box, so that the bucket was visible through the window. Treat type in the bucket was a thin layer of pellets, and then 1 piece of apple, 1 piece of pear, and 1 piece of carrot (All types).

Exposure 2

The bucket was placed behind the mirror, and hidden from view. The thought behind this was to show that when the bucket was behind the mirror, it was different from when the

bucket was behind the window, as you can see through a window, but not through the mirror. Treat type was all types, as in the previous exposure.

Exposure 3

This was the first time the goats were alone in the exposure, without a partner. Therefore I wanted to make it easy for them to find the bucket and see it right away when they came into the pen, so that the focus would be on getting the treats from the bucket (as opposed to focusing on being separated from the other goats, if there had been no bucket in sight). The bucket was in front of the mirror, same as in exposure 2 on Day 2, but on the opposite side now (left/right). Treat type was all types, as in the previous exposure.

Exposure 4

This was also a solo-exposure, to prepare the goats for the individual tests the next day on Day 4. The bucket was now hidden on the floor behind one of the mirror-window barriers (LMWB or RMWB), and the hole on this barrier was covered with a black blanket. The mirror was on the floor against the wall of the pen (behind line 2 or 3), showing a mirror-reflection of the bucket (see Fig. X.). Treat type was one piece of each (apple, pear, carrot) or whichever was left (if I ran out of some sorts, which happened a few times in the beginning).

DAY 3

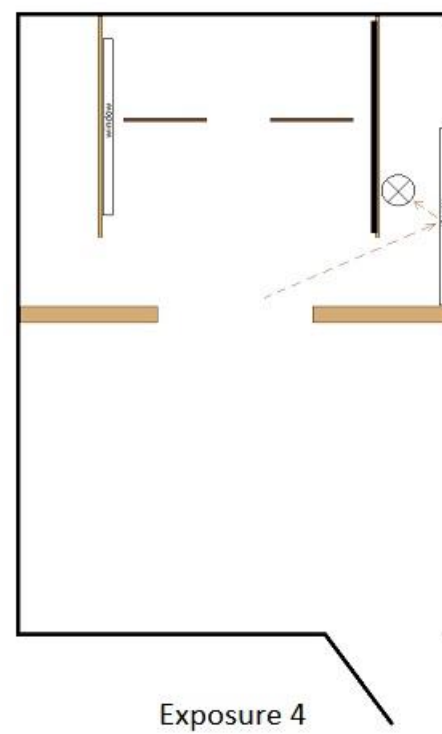
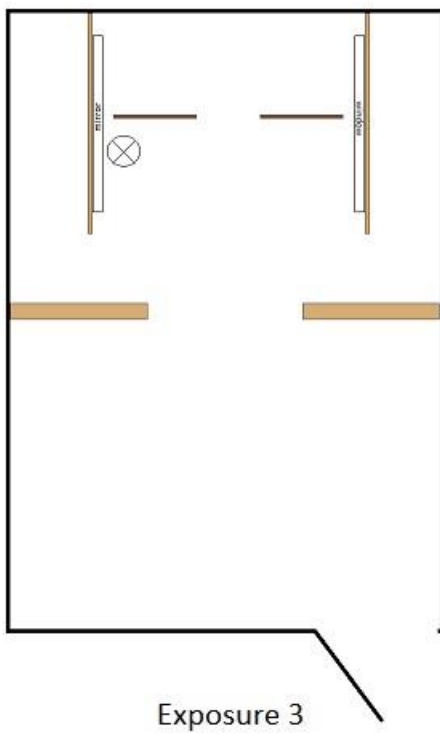
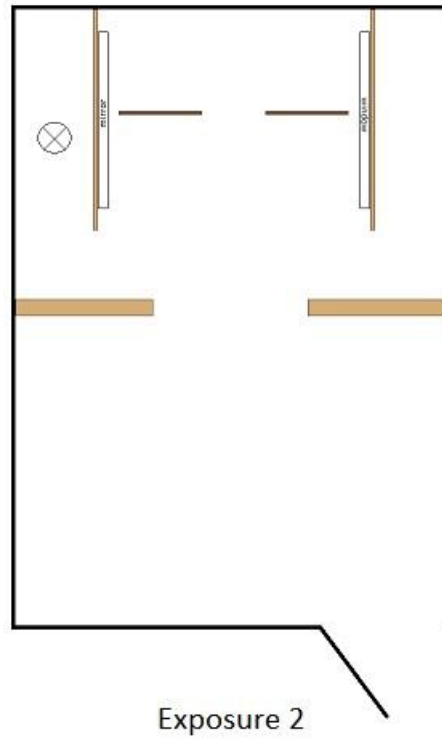
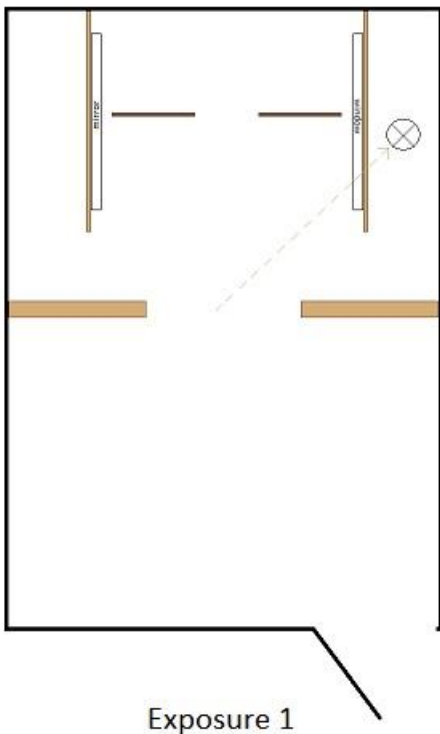


Fig. 5. Day 3 with the 4 exposures, showing where the bucket and mirror was placed. *Exposure 1)* The bucket was on top of the box behind the window and visible through the window. *Exposure 2)* The bucket was hidden behind the mirror and not visible unless looking

behind the mirror. *Exposure 3*) The bucket was in front of the mirror. *Exposure 4*) The mirror was on the floor against the wall to the left or right behind line 2 or 3, and the bucket was hidden behind the left or right mirror-window barrier, only visible in the mirror-reflection.

2.4.3. Testing (Day 4)

On Day 4 there were no treats in the bucket, to rule out that the goats would use olfactory senses to find the bucket. As soon as the goat found the bucket, the session was ended, and I went inside with the identical bucket with treats and replaced the empty bucket where it was, in order to keep them motivated for the next tests. The first two tests were Mirror condition on opposite sides, the next two tests were Window conditions on opposite sides, and the last test was a Mirror condition again (M-M-W-W-M) (see Fig. 6.). Half of the goats started to the left, and half to the right, and the next test was on the opposite side.

The data from the 25 goats that participated on Day 4 was included in the results (Not included: GoatID 40 who got sick and was replaced between Day 2 & 3, and GoatID 470 who started giving birth earlier than expected, after Day 3, and could therefore not participate on Day 4).

Test 1

The bucket was hidden behind one of the back divider barriers (LBDB or RBDB) but visible in the mirror-reflection (see Fig.A.4 in Appendix). The correct way to reach the bucket was by going straight ahead to the back in the middle, crossing line 4.

Test 2

The mirror was now on the other barrier (LMWB or RMWB), and the bucket was hidden behind the other of the two back divider barriers, and visible in the mirror-reflection on the mirror/window-barrier on the other side (left/right). The correct way to reach the bucket was by going straight ahead to the back in the middle, crossing line 4.

Test 3

The bucket was behind the window, in the same position as would have been the mirror-image of the bucket (see Fig.A.5 in Appendix). The correct way to find the bucket was by going in to the left or right crossing line 2 or line 3 (depending on whether the window was on the left or the right barrier, LMWB or RMWB).

Test 4

The bucket was behind the window again, but now on the opposite side as previous exposure (Left vs Right side).

Test 5

This was the third mirror-test, and served as a final test to see if the goats understood the difference between window and mirror, after having two tries at both, on both sides.

DAY 4

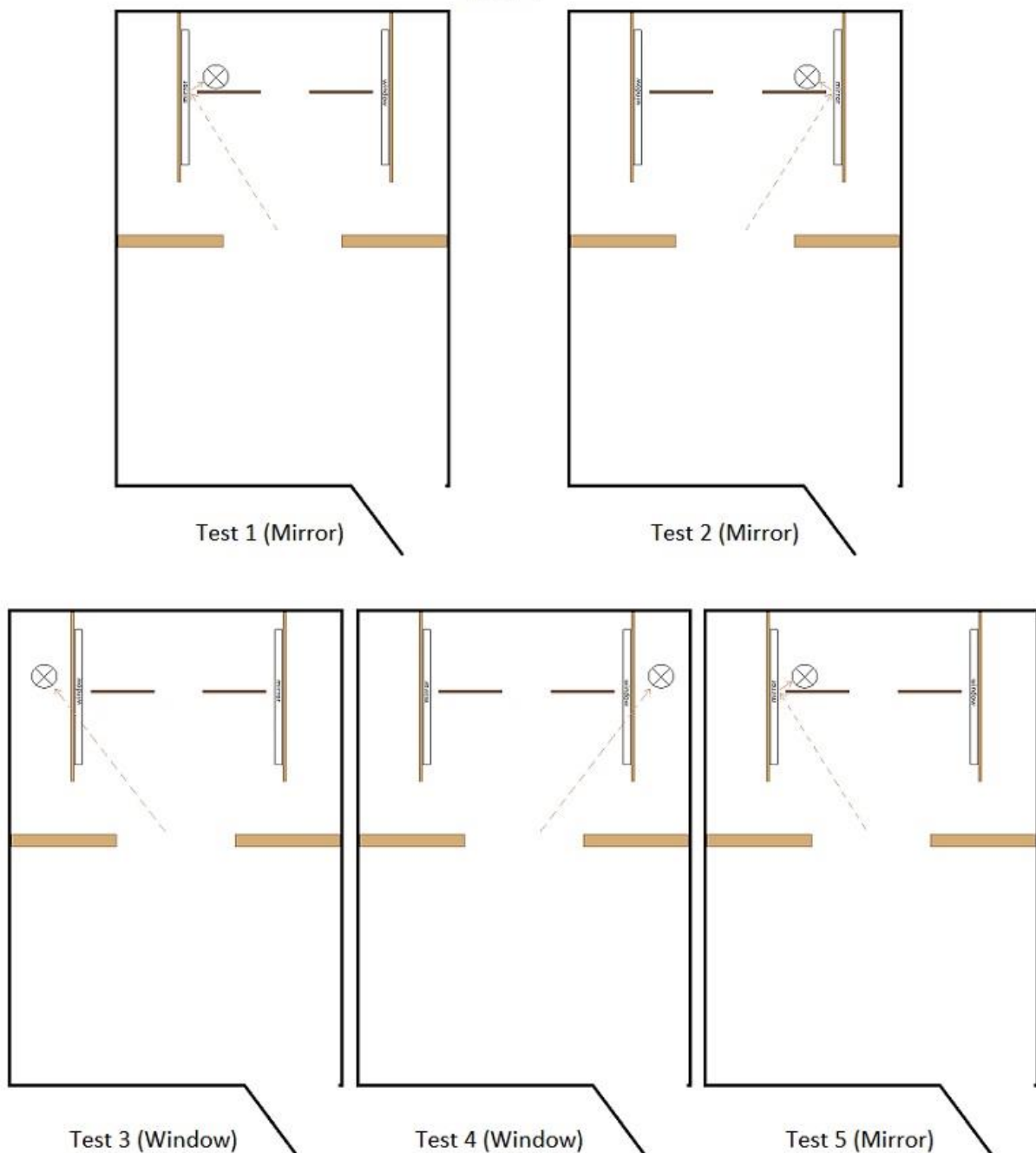


Fig. 6. Day 4 with the 5 tests, showing where the bucket and mirror was placed. In all tests, the mirror and window were placed on the left or right mirror-window barriers. In tests 1, 2 and 5, the bucket was behind the left or right back divider barrier, hidden from plain view, but visible via the mirror-reflection. In tests 3 and 4 the bucket was placed behind the window (in the same position as the bucket appeared to be in the mirror-tests) and visible through the window.

Marktest

The mirror was placed as in exposure 1 on Day 1 (see Fig. 3), but at first the mirror was covered with a black blanket. In front of the (covered) mirror, the goat was given treats (pellets) in the bucket, and while the goat's head (and eyes) was inside the bucket, the "mark" was gently and quickly attached to the goat's beard, so not to be noticed. I then let the goat finish eating, and left the pen to stand on the outside. After the goat finished eating, I waited 30 seconds before I removed the blanket by pulling a string/rope. This was to see if the goat immediately would feel the ribbon/mark in the beard and try to remove it, before seeing the mirror. After the mirror was exposed, the goat was given 3 minutes in the pen.

The mark-test was done with 20 goats. The 1 year old goats of Week 2 (five individuals) did not participate, because they were too human-shy, and I was not able to approach them and therefore not able to attach the mark on them.

2.5. Data collection

Video Analysis & Ethograms

The video recordings were analyzed based on pre-set criteria for scoring the behavior, as described in the ethogram (see Table 2) and pre-set criteria for measurements (see Table 3). The videos were viewed in the following programmes: VLC Media Player, Windows Media Player, and Film & TV Windows store app video player (due to some computer changes, and the format of some of the old videotapes transferred that were viewable and with sound only in VLC). The data collected from the videos were entered in Excel forms in ".xls" format, in the Microsoft Office compatible program Apache OpenOffice (version 4.1.2).

Table 2. Ethogram with description of the analyzed behavior.

Variables:	Definition of behavior:	Measured by:	Code:
Ate	Whether the goat ate treats from the bucket or not.	Chewing jaw movements. Yes = 1 No = 0	Ate
Total times ate	How many of the 10 exposures on Day 1-3 each goat ate treats. (Recorded because it might have to do with motivation for finding the bucket in the following exposure).	The total sum of variable "Ate" from the first 3 days. (Used in combination with the Day 4 results).	TTimesAte
Look Mirror Times	How many times per exposure a goat looked towards the mirror,	When the line/angle from eyes, or position of ears, were pointed in	

	on days 1-3 (number of times).	the direction towards mirror-surface. (For example of look not counted, see Fig.A.6 in Appendix).	
Total Times Look Mirror	How many times in total, during the ten exposures on Day 1-3, the goat looked in/towards the mirror (total number of times).	The total sum of variable "Look Mirror Times" from the first 3 days.	TTimesLookMirror
Look Window Times	How many times per exposure a goat looked towards the window, on days 1-3 (number of times).	When the line/angle from eyes, or position of ears, were pointed in the direction towards mirror-surface. (For example of look not counted, see Fig.A.6 in Appendix).	
Total Times Look Window	How many times in total, during the ten exposures on Day 1-3, the goat looked through/towards the window (total number of times)	The total sum of variable "Look Window Times" from the first 3 days.	TTimesLookWindow
Look Mirror Duration	How long the goat looked in the mirror in each exposure, on days 1-3 (in seconds).	Start time when line/angle of eyes first hit the surface of the mirror, end when line of sight goes outside of mirror-surface.	
Total duration of looking in Mirror	How many seconds of looking in mirror in total over ten exposures during the first three days.	The total sum of variable "Look Mirror Duration" from the first 3 days.	TLookMirrorDuration
Look Window Duration	How long the goat looked through/towards the window in each exposure, on days 1-3 (in seconds).	Start time when line/angle of eyes first hit the surface of the window, end when line of sight goes outside of window-surface.	
Total duration of looking in Window	How many seconds of looking through the window in total over ten exposures during the first three days.	The total sum of variable "Look Window Duration" from the first 3 days.	TLookWindowDuration
Look behind mirror	When goat looked behind the mirror, directly after looking in the mirror (number of times).	When looking behind to the side of the mirror when mirror was on a barrier, or behind & over the mirror when mirror was on the floor, and within 5 seconds of (after) looking in the mirror.	LookBehindMirror
Total times look behind mirror	How many times the goat looked behind the mirror in total over the ten exposures in the first three days.	The total sum of variable "Look Behind Mirror" from the first 3 days.	TTimesLookBehindMirror
See other goat through the window	How many times the goat saw the other goat through the window per exposure in the first three days (number of times).	When the goat saw the other goat through the window, because the other goat was visible in a line/angle of view and the goat's eyes were directly pointed towards the other goat.	SeeOthrGoatThroughWindow
Total times see other goat through window	How many times the goat saw the other goat through the window in total over the ten exposures in the first three days.	The total sum of variable "See other goat through the window" from the first 3 days.	TTimesSeeOtherGoatWindow
Latency	Time it took for the goat to find the bucket in the tests on Day 4	Day 4 Latency to Find Bucket in seconds from moment the goat	

	(in seconds).	passed line 1 until head in bucket, Dot (.) if didn't find the bucket in the 90 seconds exposure	
Latency to find the bucket	The time it took for the goat to find the bucket, in each exposure on days 1-3 (in seconds).	Start point from time when goat crossed Line 1 with one front foot, until reached the bucket with head within approximately 20 cm of bucket.	LatencyFindBucket
Total latency to find the bucket	How many seconds it took to reach the bucket combined for all ten exposures on days 1-3.	The total sum of variable "Latency to find the bucket" from the first 3 days.	TLatencyFindBucket
Reach Bucket First	Which of the goats in a pair reached the bucket first per exposure on days 1-3.	First = 1, Last/second = 0, if both reached the bucket at the same time = 0.5	
Total Times Reach Bucket First	In how many of the ten exposures did each goat reach the bucket first of the two in a pair (if any).	The total sum of variable "Reach Bucket First " from the first 3 days.	TTimesReachBucketFirst
Look Mirror Self	How many times the goat looked at herself in the mirror-reflection per exposure (number of times).		LookMirrorSelf
Total Times Look Mirror Self	How many times looking at self in mirror-reflection in total from the ten exposures on days 1-3.	The total sum of variable "Look Mirror Self" from the first 3 days.	TTimesLookMirrorSelf
Look Mirror Bucket	How many times the goat looked at the mirror-reflection of the bucket per exposure (number of times).		
Total Times Look Mirror Bucket	How many times looking at mirror-reflection of the bucket in total from the ten exposures on days 1-3.	The total sum of variable "Look Mirror Bucket" from the first 3 days.	TTimesLookMirrorBucket
Look Mirror Other Goat	How many times the goat looked at the mirror-reflection of the other goat per exposure (number of times).		
Total Times Look Mirror Other Goat	How many times looking at mirror-reflection of the other goat in total from the ten exposures on days 1-3.	The total sum of variable "Look Mirror Other Goat" from the first 3 days.	TimesLookMirrorOtherGoat
Touch Mirror	How many times the goat touched the mirror per exposure on days 1-3 (number of times).	When touching the front of the mirror with the front body (nose/face, front leg, or rubbing against the mirror sideways)	
Found	When goat found the bucket on Day 4 tests.	On day 4 found bucket in 90 secs, Yes = 1, No = 0	Found
Total times found bucket	Total times found the bucket in Day 1-3 exposures.	Added up how many "YES" (=1), so ended up with a number between 1-9, because there were 9	TtimesFoundBucket

		exposures with buckets.	
Crossed Correct Line	When goat went to the correct place where the bucket was in the tests on Day 4, by crossing one of the three lines (line 2, 3 or 4).	When goat crossed the line with one front foot, or part of the head was above/beyond the line so that the goat actively looked in there (meaning the goat saw the bucket). . = didn't cross line 1 = crossed correct line on FIRST TRY 2 = crossed correct line on SECOND TRY 3 = crossed correct line on THIRD TRY (or more)	CrossLine
Choice	On day 4, if goat found bucket (on whichever number of tries), whether it was by choosing to look the right place, or if accidentally saw the bucket directly through the gap between the two back divider barriers (in mirror tests).	1 = chose correctly where to go (guessed right) 2 = Saw bucket directly by mistake;(eg. if was standing close to back barriers and turned head towards back, so could see bucket) 3 = Not sure	CorrectChoice

Table 3. Description of other variables used in data collection and processing.

Variable names:	Definition of non-behavior variable:	Measured by:	Code:
Session Duration	How long each exposure lasted (in seconds).	Start time point was set to the second when the (first) goat (if two goats) was first seen (with any body part, such as ear, etc.) in the frame on Camera 1 (as this was most often also the same time, or no more than 1 second after, the goat entered the pen through the door). End time was set X minutes later (ex. If an exposure was set to last 5 minutes, and Start time was 0:20 on the video timeline, then the End time was set to 5:20).	SessionDuration
Total Duration Sec	Total amount of time of exposures the goat participated in on Days 1, 2, 3 (in seconds).	A summation of results from Day 1, 2 and 3 (used in combination with the Day 4 results).	TDurationSec
Exposure	Exposure Test number on day 4.	Test 1, 2 , 5: Mirror Test 3, 4: Window	Exposure

Week	1, 2 or 3 – different batch of goats studied in each week (Week 1 had 12 goats, Week 2 had 6 goats, Week 3 had 8 goats, based on their schedule for expected parturition).	Group of goats (3 groups and each group participated in 4 days of exposures/tests within a weeks time).	Week
Day	Which number of day with exposures or tests it was for that group (in the same "Week").	4 days in total for each group/week (although not consecutive days) with exposures and tests.	
Exposure Per Day	Which number of exposure it was per day (Day 1 and 2 had three exposures, Day 3 had four exposures).	(In STAT123 form with data from days 1-3).	ExposurePerDay
Exposure Number	Days 1-3 consecutive exposure numbers (ten exposures in total).	Exposures 1 – 10 on days 1 – 3.	ExpNumber
Condition	MIRROR or WINDOW on day 4, bucket visible in mirror-reflection or through window (M-M-W-W-M) (varied between right and left)	-	Condition
Goat ID #	Individual identification number on ear tag of each goat.	-	GoatID
Age	Age in years	-	Age
Previous Experience	Whether the goats had seen a mirror before. "New" goats had no previous mirror experience. From the previous mirror study four months prior to this study, "ME" (mirror experienced) goats had 4 days of mirror experience, while "MN" (mirror naïve) goats had 1 day of mirror experience.	Previous mirror experience: New – none, ME – mirror exposed in HET300 study in fall 2014 4 months previous over 4 days, MN – control in HET300 – mirror naïve, except in test day 4	PrevExp
Pair Number	Which two goats were together in the first 8 exposures on Day 1-3.	A number assigned for each pair of goats placed together during training and trials (pair 1, 2, 3, etc.).	PairNumber

2.6. Statistical analyses

Data were analysed using the generalised linear mixed model procedure (Proc Glimmix) in SAS/Stat 9.4 software (SAS Institute Inc., Cary, NC, USA). Four models were used to assess effects on the test day response variables Found (binomial), Latency (continuous), Cross First (binomial), Correct (binomial), and Latency Correct (continuous).

Variables with a binomial distribution had a logit link function, and continuous variables were analysed with a gamma distribution and log link function. Goats were the subjects and pairwise means comparisons were based on differences in least squares means with multiple comparisons adjusted using the Tukey option. The first model examined effects of Age, Previous Experience, and Exposure, with Exposure as a Random effect. The model contained one additional training experience variable that varied according to the response variable (effects of Total Times Found Bucket, Total Latency Find Bucket, Total Times Reach Bucket First, Total Looks, and Total Look Duration on Found, Latency, Cross First, Correct, and Latency Correct, respectively). The second model examined the effect of the random effect Condition on the five response variables. The third model examined effects of Total Look Mirror Duration, Total Times Look Behind Mirror, Total Times Look Mirror Self, Total Times Look Mirror Bucket, Total Times Look Mirror Other Goat, Total Times Touch Mirror and the random effect Exposure on the response variables during the Mirror condition exposures (1, 2 and 5). The fourth model examined effects of Total Look Window Duration, Total Times See Other Goat Window and the random effect Exposure on responses during Window condition exposures (3 and 4).

2.7. Ethical note

Animals in this experiment were recruited from the experimental goat herd at the Norwegian University of Life Sciences in Ås, Norway. They were managed in a way common for commercial dairy goats in Norway, and legislations for keeping small ruminants and farm animals in Norway were followed. The experiment was approved by the Animal Production Experimental Centre (Senter for husdyrforsk, SHF). All efforts were made to avoid distress, pain or suffering.

3. RESULTS

The variables cross-examined in the results that formed the four models were based on the reasearch questions.

3.1. Exposures (Days 1–3)

All the goats showed interest in the mirror, the window, and in exploring by looking behind the mirror (see Video A.1 & A.2). The goats looked 2.4 times longer in the mirror versus the window. New goats spent more time looking in the mirror than the goats with previous mirror-experience. All the goats investigated by looking behind the mirror during this period. Many of the goats went straight to look where the bucket had been located the last time. One goat (GoatID 425), after not finding the bucket behind the window (behind line 2) where it was found in the previous exposure, went on to look in the corresponding area behind the mirror on the opposite side (behind line 3), and found the bucket (see Video A.3). Many goats continued to explore the different areas of the setup even after they had found the bucket and had had several sessions to explore already, like the example of GoatID 11523 on the last exposure of day 3 (see Video A.4). Many of the goats would check the bucket several times even after they had discovered that the bucket was empty of treats (while some goats did not check it again once it was empty).

The bucket was found in all exposures for 20 of the goats, and for those incidents when a goat did not find or reach the bucket (one exposure for 5 of the goats, twice for one goat, and three time for another goat) the reasons were the following: In 6 of the 10 instances, the goats did not seem interested in the bucket. In 4 of those cases line 1 was never even crossed, one crossed line 1 back out again after only 20 seconds, and the last one did not want the fruit-treats even after the session when I tried to give it. For one exposure, the shorter one on Day 3 (1.5 minutes only, bucket behind window), both the goats never reached the bucket. And for one exposure, the goat was not able to reach the bucket because it was chased away by the partner-goat throughout the whole session.

3.1.1. Interest in the mirror vs the window (control)

The total durations for all 25 goats showed that there was a higher interest in the mirror, as they spent 2.4 times longer looking at the mirror versus the window (total sums of durations for all goats, 5810/2467 seconds). The "New" goats with no prior mirror-experience

looked more in the mirror (on average 25 seconds per goat per mirror exposure) than the mirror-experienced groups "ME" (on average 16 seconds per goat) and "MN" (on average 13 seconds per goat). Time spent looking towards the window (control) was less for all three groups (approximately 8 seconds per goat per window exposure for ME/MN and 10 seconds per goat for New).

3.2. Tests (Day 4)

None of the goats were able to find the bucket correctly on the first try in all 5 tests. Only 1 goat of the 25 goats (4%) was able to find the bucket correctly on the first try in 4 out of 5 tests (80% success rate) and apparently seemed to have chosen correctly as well (versus seen the bucket by mistake), which was a 1-year old goat (Goat ID# 541). She found the bucket correctly on her first try in all 3 mirror-tests, but this was not significantly more often than predicted by chance. There were 7 goats (28%) that crossed the correct line on the first try 3 out of 5 times (60% success), seven goats (28%) 2 out of 5 times (40% success), 7 goats (28%) 1 out of 5 times (20% success), and 3 goats (12%) in 0 of 5 times (0% success rate on first try), showing that the first correct try was quite evenly distributed among the goats. However, some of the first-try successes were also found by mistake (in mirror tests, seeing the bucket directly through the opening between the left and right back divider barriers, for instance if the goat looked through the window and turned around towards the back).

Five of the twentyfive goats (20% of the goats) did not find the bucket on the last two tests (test 4 and 5).

Furthermore, the statistical tests showed that when the bucket was found correctly, the goats were more likely to find the bucket quicker (in less time on latency) in Mirror-tests as opposed to Window-tests (an 18.8 second average latency for those particular MIRROR-tests, and a 32.2 second average per WINDOW-test found).

For the goats who found the bucket, they did so on average in less time in the second than the first test of the same condition (for the first two mirror tests, and the two window tests), but spent a little more time in the last mirror-condition again (exposure 5) (see Fig.7).

Previous mirror exposure did not add to the goats' abilities to find the bucket quicker or more often on first try than the new individuals, neither did age.

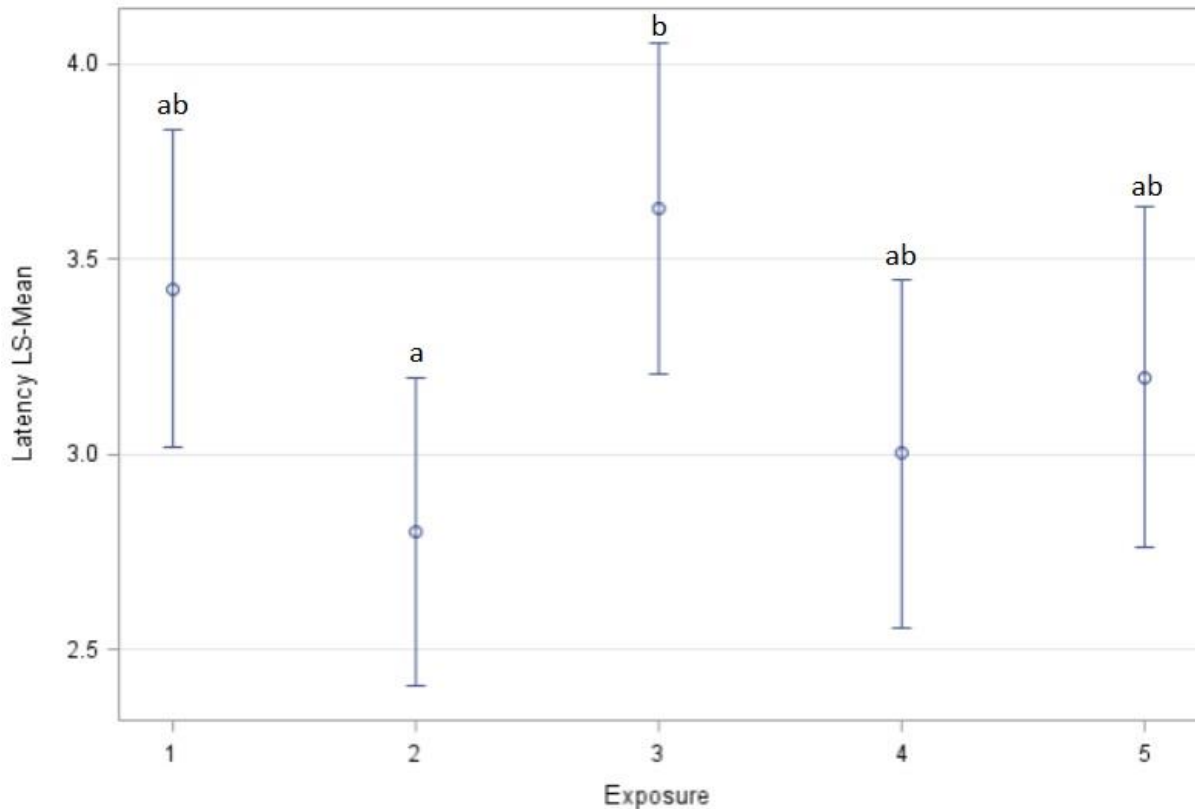


Fig.7. Least square mean (LS-Mean) latency (s) to find the bucket (with 95% confidence limits) during five successive 5-min exposures to a mirror (M) or window (W) in the sequence MMWWM on Day 4. Different letters denote significance differences at $P < 0.05$.

3.3. Test results from Day 4, combined with experiences from Day 1–3

There were no significant differences for age, previous mirror exposure, looking behind mirror (on Days 1-3), total times touched mirror, total times looking at window or seeing other goat through window, in relation to finding bucket, finding bucket correctly, latency to find bucket, or latency to find bucket when found correctly (see Table 4, 6 & 7).

A significant effect was found for the effects of exposure (MMWWM) on day 4, if bucket was found, on latency to find bucket on test Day 4 (see Fig.7).

Significance was also found on effects of exposure (MMWWM) on Day 4 on correctly finding bucket (vs not found, found by mistake, or not sure) on test Day 4, on latency to find bucket on test Day 4 and total seconds looking at mirror and window (on Days 1-3) on latency to find bucket on test Day 4 (see Table 4).

The effect of condition (Mirror vs Window) on correctly finding bucket and on latency to find bucket on test Day 4 was significant (see Table 5).

During MIRROR exposures only (exp.1,2,5), the effects of total seconds looking at

mirror and total times look at self in mirror, if bucket was found, on success in crossing correct line on first try, and if bucket was found correctly, on latency to find bucket on test Day 4, were both significant (see Table 6). A higher score on duration of looking in mirror on Days 1-3 resulted in a higher latency to find the bucket on test Day 4, although the effect was quite small.

Significant effects were also found, during WINDOW exposures only (exp.3,4), for effects of exposure (3,4) (on Day 4), if found bucket correctly, and if found bucket correctly, on latency to find bucket on test Day 4 (see Table 7).

There was a clear tendency to significant effect of total times found bucket (on Days 1-3) on success in finding bucket on test Day 4 (see Table 4), and effect of exposure (1,2,5) on Day 4, if found bucket, on success in crossing correct line on first try (vs second or third try) on test Day 4 (see Table 6). During MIRROR exposures only (exp.1,2,5), there was an almost significant tendency for the effects of total seconds looking at mirror, if bucket was found, on latency to find bucket on test Day 4 (see Table 6), and total times look at other goat in mirror, if bucket was found, on success in crossing correct line on first try (vs second or third try) on test Day 4, had a certain trend toward significance (see Table 6).

Table 4. Results for variables (Type 3 Tests of Fixed Effects) in Model 1.

Prerequisite:	Effects of variables:	..on variable:	F-value:	P-value:
For all goats:	-age (1-6 years old) -previous mirror experience -exposure (MMWWM) (on day 4) -total times found bucket (on days 1-3)	-success in finding bucket (on test day 4)	F _{1,116} = 0.73 F _{2,116} = 0.46 F _{4,116} = 0.69 F _{1,116} = 3.81	0.396 0.633 0.601 0.053
If found bucket:	-age (1-6 years old) -previous mirror experience -exposure (MMWWM) (on day 4) -total latency to find bucket (on days 1-3)	-latency to find bucket (on test day 4)	F _{1,99} = 2.07 F _{2,99} = 0.32 F _{4,99} = 3.06 F _{1,99} = 0.76	0.153 0.726 0.020 0.387
If found bucket:	-age (1-6 years old) -previous mirror experience -exposure (MMWWM) (on day 4) -total times reached bucket first (on days 1-3)	-success in crossing correct line on first try (vs 2 nd or 3 rd try) (on test day 4)	F _{1,99} = 1.49 F _{2,99} = 2.14 F _{4,99} = 1.24 F _{1,99} = 0.02	0.226 0.123 0.299 0.878
For all goats:	-age (1-6 years old) -previous mirror experience -exposure (MMWWM)(on day 4) -total times look at mirror and window (on days 1-3)	-success in correctly finding bucket (vs. Not found, found by mistake or not sure) (on test day 4)	F _{1,116} = 0.23 F _{2,116} = 0.48 F _{4,116} = 4.61 F _{1,116} = 1.16	0.631 0.620 0.002 0.283
If found bucket correctly:	-age (1-6 years old) -previous mirror experience -exposure (MMWWM)(on day 4) -total seconds looking at mirror and window (on days 1-3)	-latency to find bucket (on test day 4)	F _{1,58} = 2.50 F _{2,58} = 0.51 F _{4,58} = 2.73 F _{1,58} = 6.17	0.119 0.605 0.038 0.016

Significant effects ($P < 0.05$) are marked in **bold**, and "approaching significant"-effects ($P = 0.05-0.10$) are marked in *italics*.

Table 5. Results for variables (Type 3 Tests of Fixed Effects) in Model 2.

Prerequisite:	Effects of variables:	..on variable:	F-value:	P-value:
For all goats:	-condition (Mirror vs Window)	-success in finding bucket (on test day 4)	F _{1,48} = 2.74	0.104
If found bucket:	-condition (Mirror vs Window)	- latency to find bucket (on test day 4)	F _{1,48} = 1.41	0.241
If found bucket:	-condition (Mirror vs Window)	-success in crossing correct line on first try (vs 2 nd or 3 rd try) (on test day 4)	F _{1,48} = 0.27	0.605
For all goats:	-condition (Mirror vs Window)	-success in correctly finding bucket (vs. Not found, found by mistake or not sure) (on test day 4)	F _{1,48} = 18.04	< 0.0001
If found bucket correctly:	-condition (Mirror vs Window)	-latency to find bucket (on test day 4)	F _{1,42} = 6.06	0.018

Significant effects (P < 0.05) are marked in **bold**, and "approaching significant"-effects (P = 0.05-0.10) are marked in *italics*.

Table 6. Results for variables during MIRROR exposures only (1,2,5) (Type 3 Tests of Fixed Effects) in Model 3.

Prerequisite:	Effects of variables:	..on variable:	F-value:	P-value:
For all goats:	-exposure (1,2,5) (on Day 4) -total seconds looking at mirror -total times look: -behind mirror -at self in mirror -at bucket in mirror -at other goat in mirror -total times touch mirror	-success in finding bucket (on test day 4)	F _{2,66} = 0.99 F _{1,66} = 0.03 F _{1,66} = 0.65 F _{1,66} = 1.83 F _{1,66} = 1.03 F _{1,66} = 0.24 F _{1,66} = 0.67	0.376 0.861 0.424 0.180 0.314 0.627 0.417
If found bucket:	-exposure (1,2,5) (on Day 4) -total seconds looking at mirror -total times look: -behind mirror -at self in mirror -at bucket in mirror -at other goat in mirror -total times touch mirror	-latency to find bucket (on test day 4)	F _{2,59} = 2.07 F _{1,59} = 3.66 F _{1,59} = 2.01 F _{1,59} = 2.21 F _{1,59} = 0.50 F _{1,59} = 1.15 F _{1,59} = 0.23	0.135 0.061 0.161 0.143 0.483 0.287 0.632
If found bucket:	-exposure (1,2,5) (on Day 4) -total seconds looking at mirror -total times look: -behind mirror -at self in mirror -at bucket in mirror -at other goat in mirror -total times touch mirror	-success in crossing correct line on first try (vs. 2 nd or 3 rd try) (on test day 4)	F _{2,59} = 3.06 F _{1,59} = 10.09 F _{1,59} = 0.67 F _{1,59} = 6.88 F _{1,59} = 1.10 F _{1,59} = 3.11 F _{1,59} = 1.24	0.055 0.002 0.415 0.011 0.300 0.083 0.269
For all goats:	-exposure (1,2,5) (on Day 4) -total seconds looking at mirror -total times look: -behind mirror -at self in mirror -at bucket in mirror -at other goat in mirror -total times touch mirror	-success in correctly finding bucket (vs. Not found, found by mistake or not sure) (on test day 4)	F _{2,66} = 0.41 F _{1,66} = 0.71 F _{1,66} = 2.68 F _{1,66} = 0.03 F _{1,66} = 0.03 F _{1,66} = 0.29 F _{1,66} = 0.00	0.666 0.404 0.107 0.855 0.856 0.593 0.975
If found bucket correctly:	-exposure (1,2,5) (on Day 4) -total seconds looking at mirror -total times look: -behind mirror -at self in mirror -at bucket in mirror -at other goat in mirror -total times touch mirror	-latency to find bucket (on test day 4)	F _{2,19} = 0.57 F _{1,19} = 11.23 F _{1,19} = 0.33 F _{1,19} = 8.91 F _{1,19} = 0.72 F _{1,19} = 2.02 F _{1,19} = 0.39	0.574 0.003 0.573 0.008 0.408 0.171 0.541

Significant effects ($P < 0.05$) are marked in **bold**, and "approaching significant"-effects ($P = 0.05-0.10$) are marked in *italics*.

Table 7. Results for variables during WINDOW exposures only (3,4) (Type 3 Tests of Fixed Effects) in Model 4.

Prerequisite:	Effects of variables:	..on variable:	F-value:	P-value:
For all goats:	-exposure (3,4) (on Day 4)	-success in finding bucket (on test day 4)	$F_{1,46} = 0.47$	0.496
	-total seconds looking at window (on days 1-3)		$F_{1,46} = 0.08$	0.781
	-total times seeing other goat through window (on days 1 – 3)		$F_{1,46} = 0.22$	0.642
If found bucket:	-exposure (3,4) (on Day 4)	-latency to find bucket (on test day 4)	$F_{1,36} = 4.81$	0.035
	-total seconds looking at window (on days 1-3)		$F_{1,36} = 2.65$	0.113
	-total times seeing other goat through window (on days 1 – 3)		$F_{1,36} = 0.02$	0.886
If found bucket:	-exposure (3,4) (on Day 4)	-success in crossing correct line on first try (vs 2 nd or 3 rd try) (on test day 4)	$F_{1,36} = 0.01$	0.920
	-total seconds looking at window (on days 1-3)		$F_{1,36} = 0.02$	0.897
	-total times seeing other goat through window (on days 1 – 3)		$F_{1,36} = 0.27$	0.610
For all goats:	-exposure (3,4) (on Day 4)	-success in correctly finding bucket (vs. Not found, found by mistake or not sure) (on test day 4)	$F_{1,46} = 0.92$	0.341
	-total seconds looking at window (on days 1-3)		$F_{1,46} = 0.75$	0.391
	-total times seeing other goat through window (on days 1 – 3)		$F_{1,46} = 0.21$	0.645
If found bucket correctly:	-exposure (3,4) (on Day 4)	-latency to find bucket (on test day 4)	$F_{1,35} = 4.33$	0.045
	-total seconds looking at window (on days 1-3)		$F_{1,35} = 2.01$	0.166
	-total times seeing other goat through window (on days 1 – 3)		$F_{1,35} = 0.07$	0.795

Significant effects ($P < 0.05$) are marked in **bold**, and "approaching significant"-effects ($P = 0.05-0.10$) are marked in *italics*.

3.4. Mark test

None of the 20 goats that participated in the marktest, tried to remove the mark (ribbon) neither before nor after the mirror was exposed. Most of the goats, 15 out of 20 (75%) looked behind the mirror between 1-3 times within the 3 minutes of mirror exposure. Number of times and duration looking in mirror varied (for details, see data file for Marktest in Appendix). One goat even seemed somewhat aggressive towards the mirror-reflection, immediately followed by a peak behind the mirror.

4. DISCUSSION

4.1. Exposures (Days 1-3)

The aim for this study was to see whether, after several days of mirror experience, goats would be able to solve a problem using a mirror as a tool, and if they would demonstrate via a marktest that they recognized themselves in the mirror-reflection during Day 4 tests.

The results from Days 1-3, which was a learning- and habituation period, showed the goats' great interest in the mirror, looking 2.4 times longer in the mirror versus the window. However, this could be due to having more exposures where the bucket was by the mirror rather than the window. Although when finished eating, the goats had a lot of time left for exploration, and they soke out the mirror also in window-exposures, and in general the mirror seemed to be of more interest. New goats spent more time looking in the mirror than the goats with previous mirror-experience, which was not surprising considering that it is typical for animals to attend more strongly to novel than familiar objects (Antunes & Biala, 2012). Many of the goats relied on their memory in the next exposure and went straight to look where the bucket had been located the last time. This result is consistent with a previous report that goats rely on spatial memory to locate previously discovered sources of food (Briefer et al., 2014). The goat in the video mentioned (GoatID 425), after not finding the bucket behind the window where it was found in the previous exposure, went on to look in the corresponding area behind the mirror on the opposite side, and found the bucket. This shows exploratory behavior, and maybe even reasoning, since it tried there next instead of looking in the back behind line 4. Another example of exploratory behavior was that many goats continued to explore the different areas of the setup even after they had found the bucket and had had several sessions to explore already, raising the question as to whether it was to check if there was another bucket somewhere as well.

Regarding memory, there were several examples of goats that would check the bucket several times even after they had discovered that the bucket was empty of treats (while some goats did not check it again once it was empty). Had they forgotten, or were they checking if it had been refilled? Or was it just a part of their curious nature when it comes to searching for food? Same as for humans who differ in degree of memory, there could also be individual differences between goats' memory, as well as eagerness to search for food.

The bucket was found for 20 of the goats in all ten exposures. For the shorter exposure on Day 3 (1.5 minutes only, bucket behind window), both the goats never reached the bucket.

GoatID 3055 was one of those who seemed uninterested to find the bucket in an exposure the day before, but this time looked through the window throughout the whole session, so maybe it just was not enough time to figure out how to get there. For the partner-goat (2121) this was actually the first session, since taking over for the sick goat, so she spent the whole session looking at the mirror and behind the mirror several times (therefore not finding the bucket behind the window).

4.2. Tests 1-5 (Day 4)

The results showed that the goats did poorly on the tests on Day 4 with regards to the use of the mirror to solve the problem of finding the hidden bucket immediately (on first try, and choosing correctly rather than seeing the bucket by mistake). The goats did use their sense of curiosity to search for the hidden bucket, and some goats did better than others, but none was consistent in using the mirror to locate the bucket in all three mirror-tests. One goat, 541, found the bucket correctly on her first try in all 3 mirror-tests, but this was not significantly more often than predicted by chance. The goat was heading straight to the back anyways (perhaps remembering the location), looking both to the window, and to the left in the back as well as to the right where the bucket was located. Had the goat truly understood the mirror-reflection and where the bucket had to be placed, it would have headed straight there.

The statistical tests indicated a significant effect of condition (mirror vs window) on correctly finding bucket and latency to find the bucket. The bucket was found correctly more often in window-tests, but quicker in mirror-tests than in window-tests. These results suggest that the mirror was harder to use to find food than the window, but the window was not easy to use by the goats either. Maybe, had the goats only seen a bucket through a window and not had a mirror in the equation as well, they would have figured it out sooner, but in this setup were confused because the mirror exposures were different and therefore they did not jump to conclusions about the window either. Finding the bucket quicker in mirror-tests could also be explained by there being three mirror-tests, in which the correct place to look was straight ahead to the back, across line 4, whereas in the window-tests, the correct places to go were two different lines, 2 and 3.

It was not surprising to see that latency dropped from the first to the second of the same condition (first mirror test versus the second, and the first and second window tests, and that the latency for the third mirror-test (the fifth test) after two window-tests, was a little higher than the previous mirror-test, but still lower than the very first mirror-test. These

results suggest that the goats were continuing to learn during the test exposures.

Some of the goats, however, looked in the same place twice (wrong choice) during the same exposure on Day 4. For example if the bucket was behind the window or in the back (line 4), some individuals looked behind the mirror, and then again, despite not having seen a bucket there. There could be three possible explanations: 1) the goat did not remember that there was no bucket there or had to check again, with a possible factor of poor memory due to stress, 2) the bucket (behind the window) was visible in the distance in the mirror-reflection, so the goat actually saw the bucket in the mirror, leading the goat to think it was behind there (and thereby also not understanding the concept of the mirror), or 3) the goat saw her own reflection in the mirror and thought it was another goat, which had to be investigated (and more important than finding the bucket), implying that she did not recognize herself and demonstrating a non-understanding of the mirror-concept.

The results showed that a higher score on duration of looking in mirror on days 1-3 resulted in a higher latency to find the bucket on test day 4 (significant effect, although small). This could indicate that goats who understood quicker, needed less time of looking in the mirror, and was quicker to find the bucket on the test day, while the goats who spent more time looking in the mirror did do because they did not understand, and therefore also took longer to find the bucket on the test day. A study of human children that compared children with Down syndrome (DS) and without (NDS) found that although both groups could solve the mirror-related tasks, children without (NDS) lost interest more quickly, whereas children with DS would be more attentive to the mirror, showing a difference in attention, exploration and motivation (Loveland, 1987).

4.3. Previous mirror-experience or age as factors

There were no significant effects in relation to previous mirror-experience. I expected the ME-goats (with 4 days of similar exposures to mirror four months prior) to do better in the tests than the rest of the goats, especially compared to New goats. The lack of a difference suggests that a few more mirror exposures in the current study would not have improved performance, although it is possible that additional exposures over a short time period would be more effective for learning than additional exposures separated by several months.

Regarding age, I expected either that older goats would do better in the tests because they had had more learning experiences upon which to build new experiences and would therefore be less fearful and more able to learn about the mirror during exposures, or that younger goats would be more curious and therefore quicker to learn. The mirror studies in

pigs (Broom et al 2009; Gieling et al 2014) used 4-8 week old piglets, which I thought seemed a little young. No effect of age over a much wider age range (1-6 years old) was seen in this goat study.

However, it was a 1-year old (GoatID 541) who did the best on the tests (with 4 successful out of 5 tests), but it could have been due to some luck and memory. In the second mirror-test, she walked straight to the back, probably remembering from the previous test, looking to the left first (where the bucket had been), then to the right (where it was now). I counted "line 4" as a correct choice, and although it would have been better to count right versus left as two different options, I had decided that it was too difficult to determine consistently where the goat looked first. Once they had their head across that line, there was a great chance that they would see the bucket in the corner of their eye, and I figured that if they had made the decision to cross line 4, then they had made the correct choice as opposed to choosing to look in the wrong place such as behind the mirror or behind the window (lines 2 or 3).

One of the goats with previous mirror-experience (ME), GoatID 1548, illustrated that even with a total of 7 days with mirror exposures (including the previous study) before these tests, there was still confusion. In the first mirror-test, the goat looked through the window, then looked in the mirror and went behind the mirror to check (crossed line 2). She then went back over to the window and this time looked behind the window (crossed line 3), and from the very back in that section saw the bucket through the window. She then walked out over line 3, over to the mirror, and rubbed her head against the mirror, as if trying to get through the tiny crack to reach the bucket. Finally, she went around the back divider barrier, and correctly crossed line 4 (so correct on the 3rd try). In the next mirror test, it was most likely memory of location that lead her to look in the back (to the left first, although this time the bucket was to the right). The window-tests were no easier for this goat. In the first window-test, the goat looked in the mirror for a while and rubbed her head against the mirror, before going correctly behind the window where the bucket was. Whether the interest in the mirror was due to the reflection of herself in the mirror ("another goat?") or because she saw the reflection of the bucket in the mirror, I cannot answer, but despite of the experience of having found the bucket behind the window, in the second window-test, this goat looked behind the mirror again, and never found the bucket. In the third and last mirrortest (test 5), she looked behind the mirror, looked towards the window, but gave up and never found the bucket. So it seemed as if this goat, although one of the 4 goats with the most mirror-experience, had not learned enough to have success in the tests. These two examples stood out and are shown in

Video A.5. and Video A.6.

The variation in results among all the subjects in this study across age-groups and previously being tested, could possibly be explained by differences in motivational factors and individual differences in the goats' cognitive abilities.

4.4. The experimental setup

The idea behind this setup, was to make it clear whether the goats chose to go the right place in the final tests, because there was a 1/3 chance of crossing the correct line, versus a 50-50 chance in the prior study (in the HET300 project). Also, the current study balanced exposures on left vs right. However, the current setup was possibly a little too complex, adding confusion because of the placement of the mirror and window opposite each other. The window was visible in the mirror-reflection, and therefore also the bucket when placed behind the window. In addition, since there was a little glare of reflection in the window because of the lighting, so the bucket could possibly be seen weakly there as well in mirror-tests (see Fig.A.7).

It turned out to be unfortunate to have two mirror-tests right after one another; because regardless of the left vs right differentiation, the bucket was placed behind the same line for both of them, and the goats could go by location memory to find the bucket the second time.

So the experimental setup with the placement of barriers with mirror and window was not ideal, and I have since thought of another setup that might have worked better with regards to these problems mentioned above, while still keeping the side option of left/right (see Fig.8).

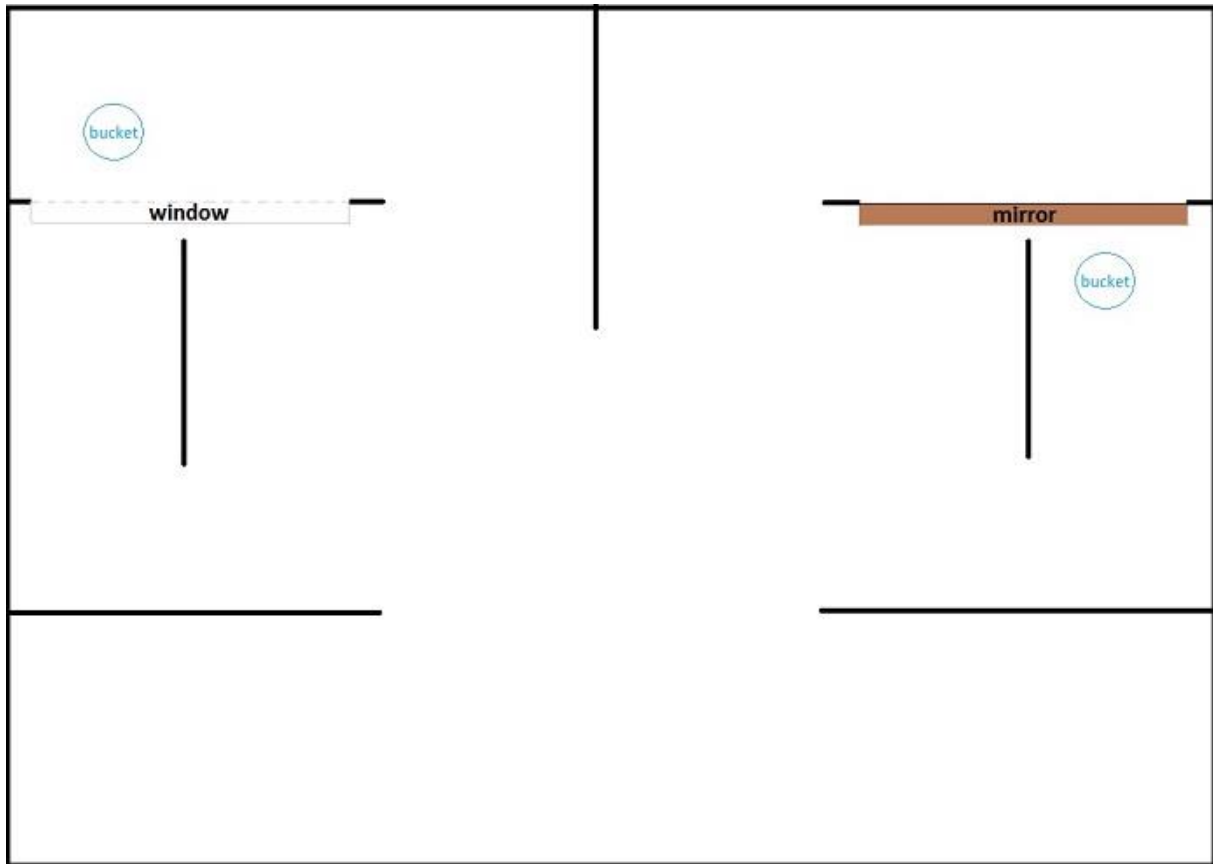


Fig.8. Showing an alternative setup for mirror and window tests on left and right sides.

4.5. Other factors (possibly influencing results or not)

Two goats were together in the first 8 exposures, so they would not be completely separated from the rest of the herd, as this can cause distress in the animals (Rutter, 2002). It is an advantage for goats to be with a familiar individual when introduced to unfamiliar goats (Patt et al., 2013), in this case if the mirror-reflection of themselves would be perceived as two unfamiliar goats. It was also to habituate them to the setup together before testing them individually. Following the experience in pairs, the goats did not seem to mind doing the individual sessions and maybe they preferred not to compete once the motivation for food rewards had been established, as most of the goats were eager to find the bucket throughout the period. However, when in pairs the goats could influence each other in the sessions, in both directions of improving or reducing results. The goat that was chased away from the bucket by the more dominant goat, was never allowed to reach the bucket, although the motivation to approach the bucket was present. It happened quite often that one goat would claim the bucket over the other, although in other cases, both goats reached the bucket in the beginning, and the subordinate would be able to eat in between the other goat raising her head

to chew. The pairing also influenced the latency to find the bucket. When the first goat had found the bucket, especially in the exposures where the bucket was not in open space, but hidden and visible via mirror, or behind the window, the other goat would immediately follow after hearing sounds of something being eaten. The latencies in these exposures might have differed for the second goat, had it been alone, but no effect was found of total latency to find bucket (on Days 1-3) on latency on Day 4. Another factor that could have possibly influenced the results for some of the goats on Day 4 tests, is that the goats that were not first to reach the bucket, might have missed the opportunities of seeing the bucket in the mirror-reflection when it was hidden (Exposure 3 on Day 1 and Exposure 1 on Day 2 when in pairs), therefore not learning that the bucket was in fact in front of the mirror, which was a crucial part of the learning process leading up to the final mirror-tests. When the goat that arrived first reached the bucket, the goat would both block the view, and would often drag the bucket out from where it was standing so that the bucket ended up being placed visible in open space. However, it was difficult to determine what the second goat saw or did not see in the beginning, before the first goat found the bucket.

The exposures and tests relied on the subjects' willingness to find the bucket, and motivation for the treats that would be found in the bucket. There were long days, and motivation could drop towards the end of the day if the goats were tired. Especially test day 4 was very long, as the goats had to go individually. Getting the correct goat for each session out of the waiting pen, keeping all the others in, that were also trying to get out, and then moving the goats, especially the social, treat-loving ones that refused to go back to the waiting pen, was time-consuming. In addition there were now 5 sessions (or 6 including Marktest), and many of the goats seemed to give up easily and did not even bother to look for the bucket in the last couple of tests (five goats did not find the bucket in the last two tests), which could have affected the results. Ideally, if I had a longer period of time in which to conduct the study, I could have spread it out with fewer goats each day to keep the days shorter, and added even more exposures before the testing, to give the subjects more learning experiences for each variation.

In the first sessions of week 1, I noticed that the goats had very sensitive ears and eyes in regards to picking up on movements and sounds. If I moved in the slightest way they would hear it and see it from the corner of their eye and turn around to look towards me, so I started watching only the camera screen above my head, in order not to disturb them in the session. Goats can follow human pointing, the direction of a human's head, and the gaze direction of other goats, but not human gaze (Nawroth et al., 2016; Kaminsky et al., 2005), so this was

not likely to be a problem in my study, and I was standing behind a cover almost not visible (see Fig.A.8).

4.6. Mark Test

None of the goats tried to remove the mark, and most of the goats looked behind the mirror, directly after looking in mirror. Some goats did so even up to 3 times during the 3 minute session. The fact that they still investigated the mirror like this, could suggest that they were unsure of what (who) they saw in the mirror and had yet to figure out what the mirror represented. When none of the goats tried to remove the ribbon, it could mean one of three options: 1) The goats did not understand that the mirror-reflection was their own reflection, 2) They did not care about the ribbon-mark in the beard, even if they noticed it in the mirror, and therefore did not try to remove it, or 3) The goats did not see the ribbon on them in the mirror-reflection, but for most of them I think it was quite visible, especially the white goats (see Fig.A.3). Regarding option 2, that they did not care, one goat got the blue rope used to hang the mirror tucked around her face and ears, with the rope across her nose, and she did not seem bothered by it, and continued walking around to investigate without trying to get the rope off. So if the goats were in fact not bothered by the ribbon-mark, then the marktest would not be a good way to test for self-awareness in goats.

Chimpanzees also lose interest in the mark, and do not see the significance in removing it, like birds do because their feathers are more essential for their survival (Prior et al., 2008).

4.7. Other reactions towards the mirror

Duration of looking in the mirror was high for some of the goats, and some individuals looked in the mirror for 20-60 seconds at a time. At first I interpreted this as a great interest in the mirror, but it could also have been an expression of a fear-response if the goat would "freeze" when faced with an unfamiliar individual (Ekesbo, 2011).

Some goats did also seem startled by their own mirror-reflection (see Video A.7 & A.8). Some looked to the side of the mirror and back, as if to check "where the other half of the body was"(see Video A.9). There did not seem to be much aggressive behavior from the goats when faced with the mirror, but Patt et al. (2013) mentions that, to reduce the risk of aggression, it is an advantage for goats to meet unfamiliar individuals together with familiar goats. However, one goat particularly seemed to react in a somewhat aggressive manner in the marktest (see Video A.10), and another one seemed to challenge the mirror-reflection by

approaching with the head lowered, stamping with the front feet and making snorting sounds (see Video A.11). According to Ekesbo (2011): "When alarmed, goats will stomp one forefoot and produce a high pitched, sneezing sound." Whether this was it, I am not certain as I could not find any video-examples and am not familiar with goats to that extent.

If the goats thought that they saw another unfamiliar goat in the mirror-reflection, it could possibly have caused stress to some degree. According to Ekesbo (2011), the stress of being put together with unfamiliar goats could provoke agonistic behavior, and could result in a decrease in learning.

4.8. Comparison to other mirror studies

Although given altogether 15-16 short sessions with a mirror over 4 days in this study, it is still not that much time with a mirror, which might have limited how much goats could process and learn about the mirror. Human children spend years with mirrors available to them every day, before they comprehend completely what the mirror represents, although they reach higher cognitive states as human beings (Swartz, 2003). In other mirror studies, chimpanzees were given 10 days with mirrors before being tested with a marktest (Keenan, 2003). Many animals, including adult dogs, avoid looking in the mirror (Howell et al., 2013), but the goats were curious and appeared interested in learning about the mirror.

There has also been speculations around the validity of the marktest when it comes to whether it shows self-recognition if the test is passed, or if the animal or infant still thinks there is another individual in the mirror, but reasons that "if the other one has a mark on the forehead, maybe I have one too, so I'd better check." This is because infants have touched their face after observing a mark on the face of another human (Mitchell, 1993).

Mirror studies are becoming increasingly popular, but to date there are only a few species of animals that have been tested with mirrors, and we still know relatively little about animals' cognitive abilities and perceptions. It is important to research this area further, because it can serve as a basis for directions on how we treat the animals, both in captivity and in natural environments.

5. CONCLUSION

To sum up the findings in this study, here are the research questions answered by the results:

- 1) The goats were not consistent in using the mirror to locate the bucket in all three mirror-tests on Day 4 with regards to the use of the mirror to solve the problem of finding the hidden bucket immediately (on first try, and choosing correctly rather than seeing the bucket by mistake).
- 2) & 3) Goats with greater historical experience with the mirror did NOT find the bucket faster or more often than goats with less or no previous experience throughout the period..
- 4) Age did NOT influence ability to find bucket faster or more often throughout the period.
- 5) The goats who scored higher on the mirror variables 'total seconds looking at mirror' and 'looking at self in mirror' on the first three days, DID do better in mirror-trials on the last day. Higher scores of looking at the window on the first three days, did not improve testday results.
- 6) The goats DID investigate the mirror more than the window, which served as a control, on the first three days.
- 7) The goats who reached the bucket faster or first more often on the first three days, did NOT do better in finding the bucket faster, on first attempt or more correctly in the trials on Day 4.

For future mirror studies in goats, I would recommend to allow the subjects to have much more time to gain experience with mirrors before testing for either mirror-tool-use in problem-solving and/or a marktest. If the goats could possibly have a safe mirror in their daily housing for months, that they could explore and learn about, seeing other individuals walk in front of it and behind it etc, that would be ideal. If given some problem-solving tests with a mirror several times during that period, and then tested in the end, that might give a better indication of whether the goats are able to use the mirror as a tool.

Cognitive challenges for goats in their daily housing could produce positive feelings of achievement and a certain degree of control over the environment, which benefits the well-being of the animals (Langbein et al. 2009). Given that goats are curious animals who seek challenges, it could be advisable to implement some enrichments to their daily housing environments.

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7. APPENDIX

VIDEOS

Video A.1. Goat staring at the mirror with its nose close to mirror, and see the other goat in mirror-reflection through the gap (the other goat is standing in the very back, where the bucket will also be seen in mirror test) (Week 3, Day 2).

YouTube link: <https://youtu.be/C6ZYc1Z0Mzw>

Video A.2. Goats looking behind the mirror (two videos in one, both from Week 2, Day 2).

YouTube link: <https://youtu.be/gr5ydpKFaLQ>

Video A.3. Goats went to look behind the window where the bucket had been the last time, then one of them goes to check behind the mirror and finds the bucket (Week 2, Day 3).

YouTube link: <https://youtu.be/nJCdUQgggo4>

Video A.4. Goat finds bucket, but keeps on searching other places (Week 1, Day 3, exp.4 alone where bucket is hidden to the side, visible in mirror reflection).

YouTube link: <https://youtu.be/4NbW-P5ZPo4>

Video A.5. Tests 1-5 on Day 4 for GoatID 541 (1 year old) who did the best in these tests, and crossed the correct line first in 4 of 5 tests.

YouTube link: https://youtu.be/9nOt0y_aWos

Video A.6. Tests 1-5 on Day 4 for GoatID 1548 (previously mirror-exposed in prior study, ME) who looked behind the mirror, and failed to find the bucket in tests 4 and 5.

YouTube link: https://youtu.be/-4OseuNSd_0

Video A.7. Goat seems to get startled by the mirror-reflection of the other goat coming closer (Week 2, Day 2, exp.2).

YouTube link: <https://youtu.be/934xYonatkc>

Video A.8. Goat is startled by its own mirror-reflection, and bounces back a little (Week1, Day3, exp.2).

YouTube link: <https://youtu.be/zT5wa4VprLQ>

Video A.9. Goat looking into the mirror from the side, head back and forth (Week 1, Day 1, exp.1).

YouTube link: <https://youtu.be/WQHRXAjrjdo>

Video A.10. Goat showing agonistic behavior towards own mirror-reflection, trying to "bite" the mirror, and then looks behind the mirror (Week 1, Day 4, Marktest).

YouTube link: <https://youtu.be/UiFgJ38-VD8>

Video A.11. Goat with possibly agonistic behavior towards the mirror; seems to challenge the mirror-reflection by approaching with the head lowered, stamping with the front feet and making snorting sounds (Week 1, Day 1, exp.1).

YouTube link: <https://youtu.be/VRqskn74jXs>

Videos will be made publicly available under the You Tube channel "GoatBehavior" after publication (these clips and more).

PHOTOS

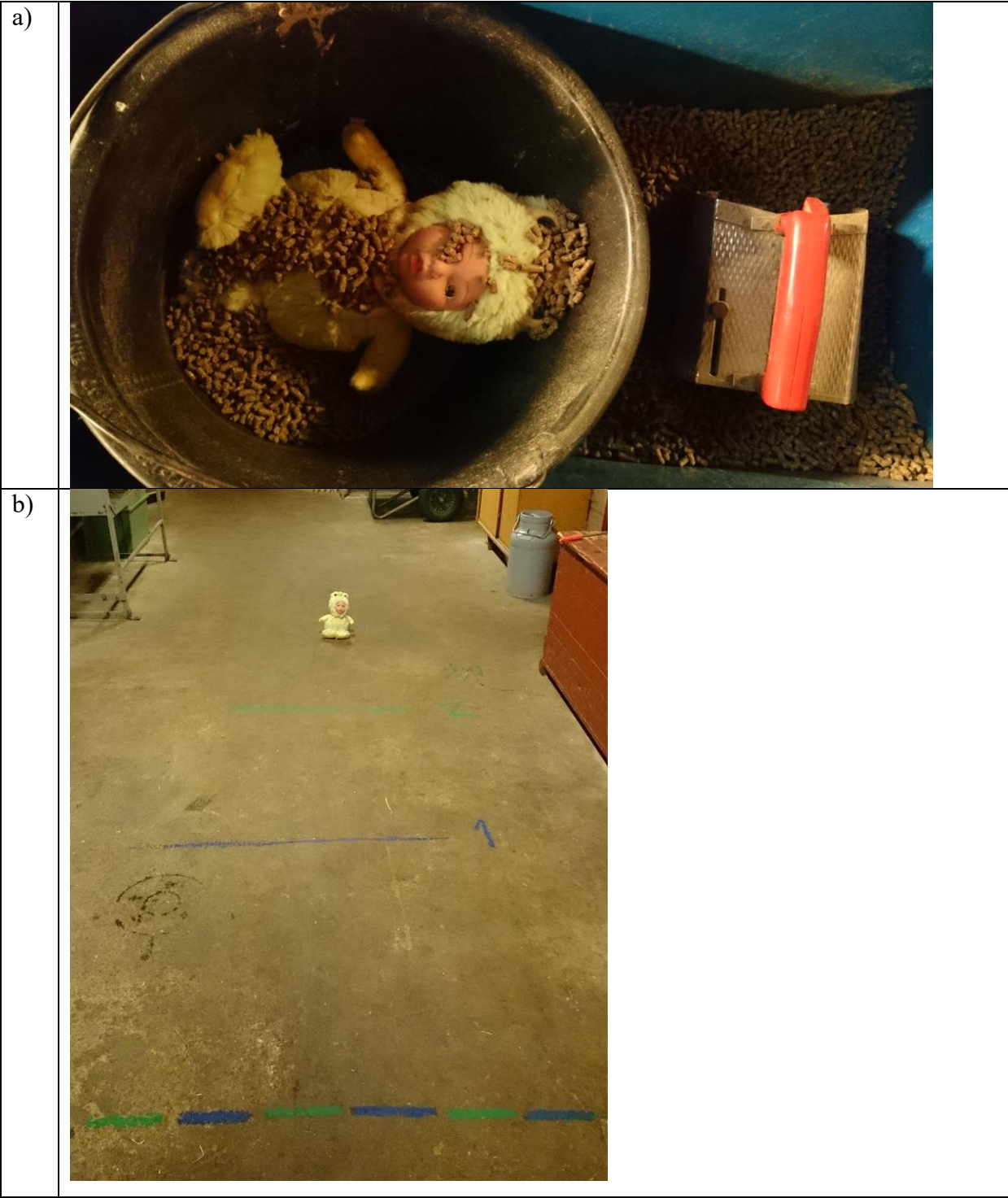


Fig.A.1. Pre-screening of *New* subjects. (a) The doll covered with pellets to carry food scent, and (b) was placed on the floor. Subjects came in individually.

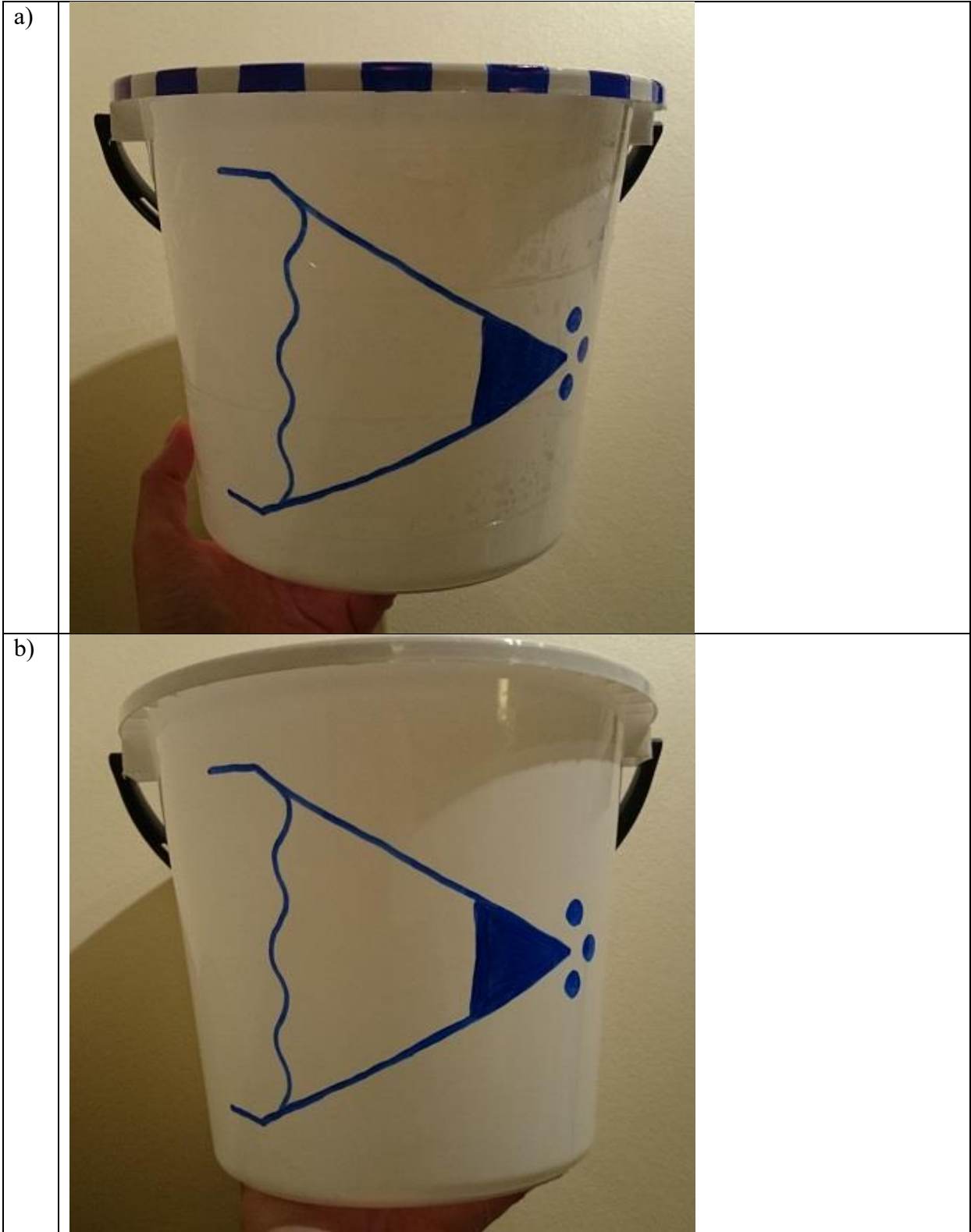


Fig.A.2. The design on the bucket (a) front, and (b) back.



Fig.A.3. The mark (ribbon) in the mark test, circled in red here to show placement in beard.



b)



c)





Fig.A.4. Mirror test setup on Day 4. (a) The bucket visible in the mirror on Day 4 mirror-tests. (b) Bucket was not visible through the gap between the back divider barriers at this point, but (c) in this point the bucket could be seen directly. (d) I tested before every session after placing the bucket, to ensure that the bucket could not be seen through the gap between the mirror and the back divider barrier.



Fig.A.5. Window test setup on Day 4. Bucket is visible through the window.

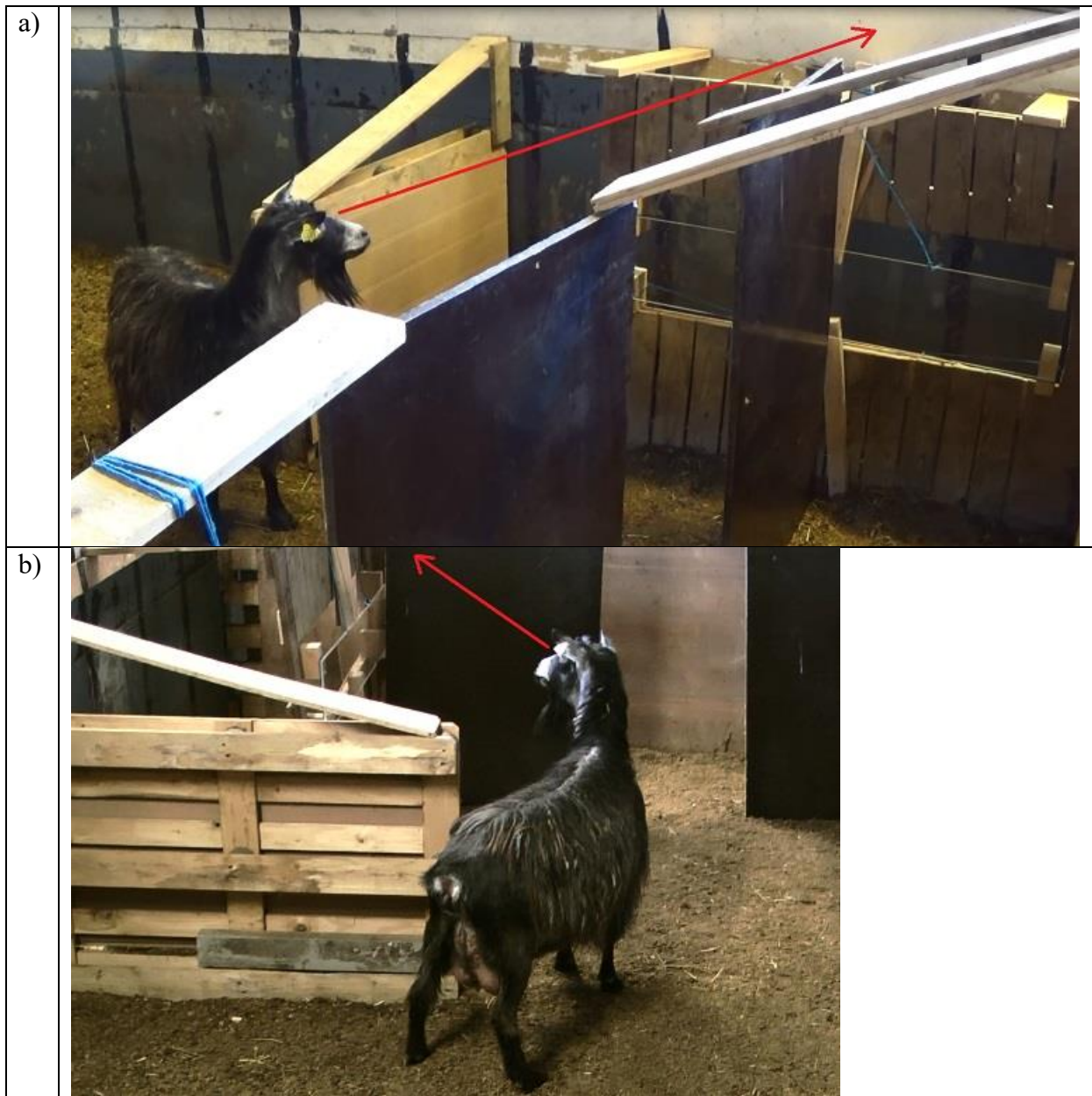


Fig.A.6. Example of look not counted (as Look in mirror, or Look at window) because the line of visibility goes up towards the top windows on the wall, by (a) head tilted upwards, (b) ears pointing upwards.

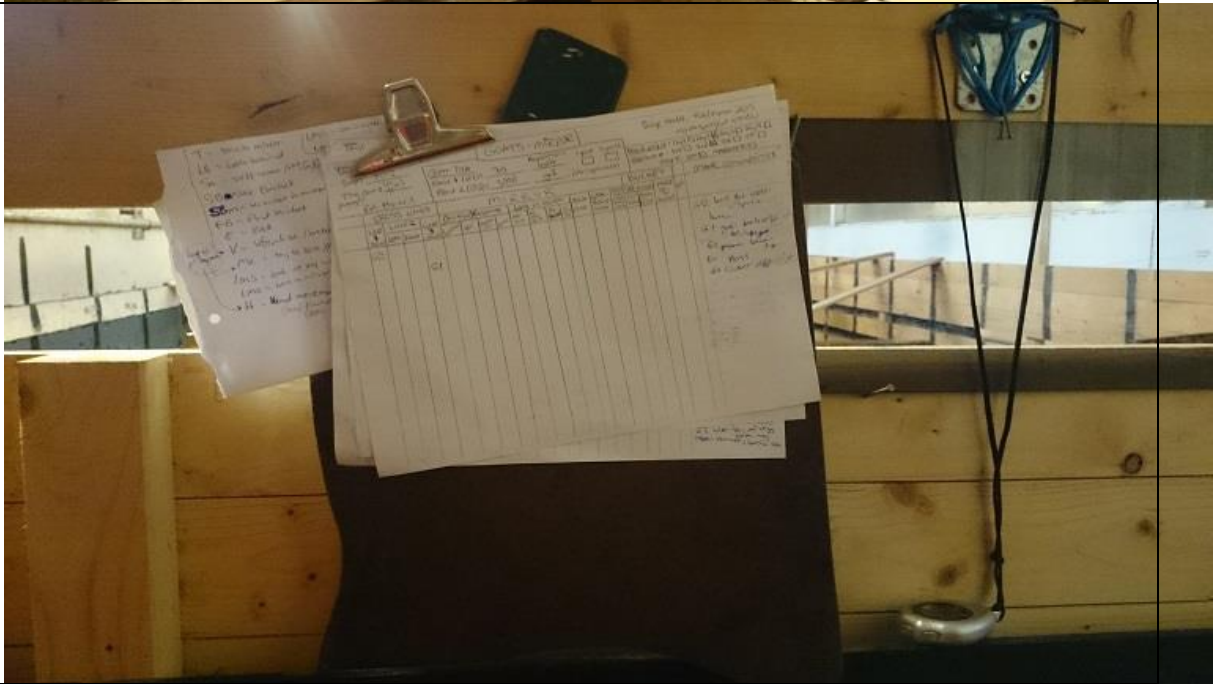


Fig.A.7. Example of (a) a glare in the window with a little bit of reflection from the bucket, (b) mirror-reflection of the window with the bucket behind.

a)



b)



c)

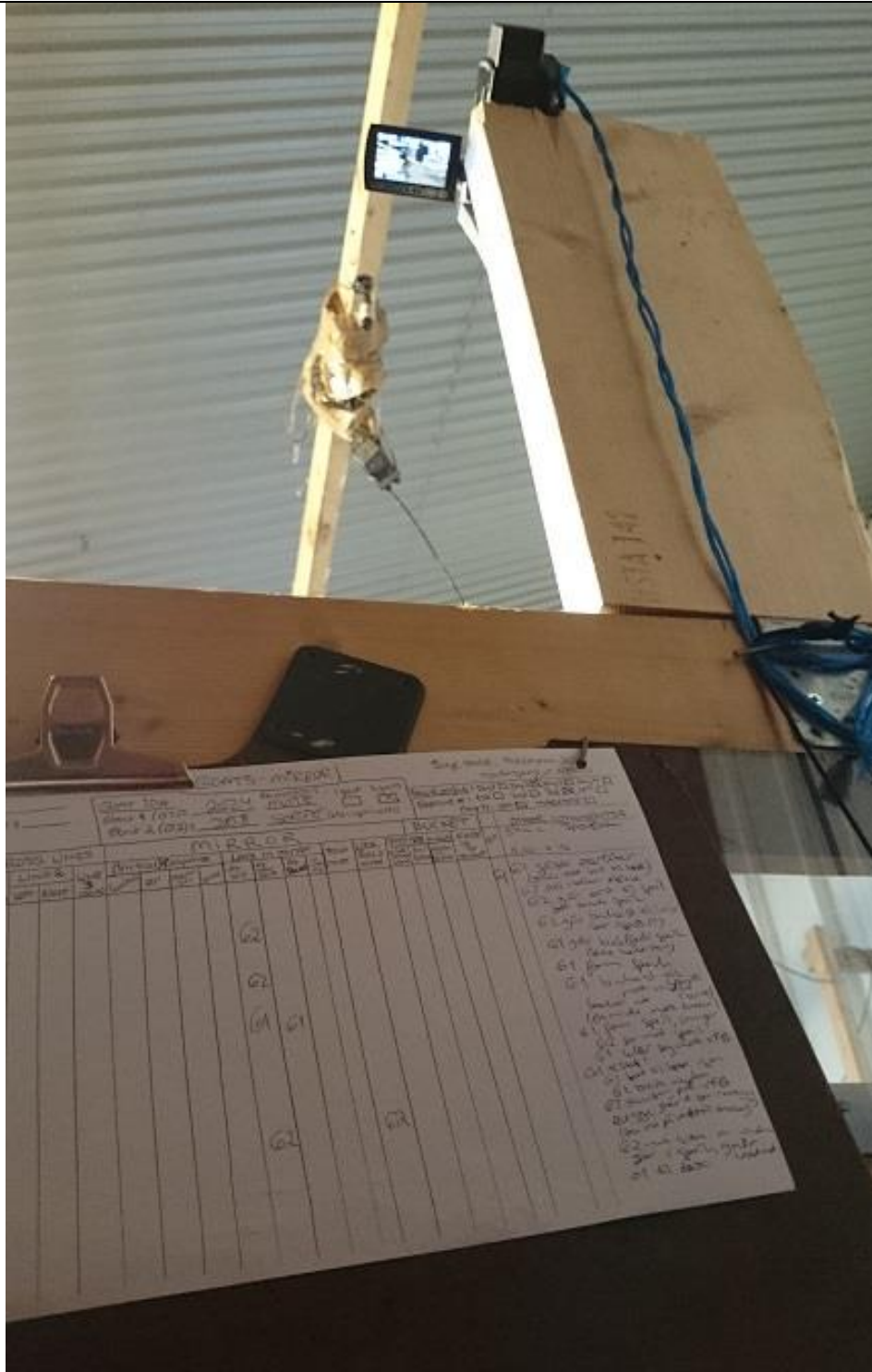


Fig.A.8. Position of observer during sessions, (a) behind cover barely visible (red circle shows top of observers head), (b) from behind the cover, and (c) using videocamera-screen to view the goats.



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