Institute of Animal Welfare Science

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Master Thesis

Prosociality in goats – Do goats use a food-giving see-saw apparatus to provide food to conspecifics?

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Zusammenfassung

Prosozialität beschreibt freiwilliges und vorteilhaftes Verhalten eines Spenders gegenüber einem Empfänger. Prosoziale Verhaltensweisen wurden bisher hauptsächlich bei Primaten untersucht. Erst in jüngster Zeit rückten auch weitere Tierarten in den Fokus des Forschungsgebiets. Dennoch ist die Forschung zu Prosozialität bei Nutztieren selten. Diese Studie versuchte Einblicke in das prosoziale Verhalten bei Ziegen zu gewinnen. Dafür wurde ein Wippen-Apparat in einem „Gruppen-Service-Paradigma" verwendet, mit dem Ziegen Artgenossen Futter zukommen lassen konnten. Die Studie bestand aus zwei Phasen: Während der Lernphase sollten die Ziegen den Umgang mit dem Apparat lernen und in der Testphase wurde das prosoziale Verhalten der Ziegen getestet.

Während der Lernphase konnten die Ziegen durch das Betreten der Plattform Gruppenmitgliedern und sich selbst Futter in Form von Nudelstücken zukommen lassen. Die Testphase bestand aus drei Stufen: Teststufe 1 und 3 waren identisch und die Ziegen konnten anderen, aber nicht sich selbst Futter zukommen lassen. Die Teststufe 2 diente als Kontrollstufe, in der allen Gruppenmitgliedern der Zugang zum Futter zu verwehrt wurde.

Entgegen unserer Hypothese zeigten die Ziegen während der Testphase keine Anzeichen von prosozialem Verhalten. Allerdings erzielte auch die Lernphase nicht die erwarteten Ergebnisse, da nur wenige Individuen den Apparat betätigten. Davon zeigten nur zwei Ziegen ein hohes Maß an Motivation und deuten möglicherweise auf ein Verständnis der vollen Funktion des Apparats hin. Dieser wurde von den Ziegen während der Lernphase allerdings hauptsächlich dafür verwendet, sich selbst Futter zukommen zu lassen.

Mehrere Faktoren während der Studie könnten das Verhalten der Ziegen gegenüber dem Apparat beeinflusst und den Lernprozess behindert haben. Dies könnte das fehlende prosoziale Verhalten während unserer Studie erklären. Weiters geben wir mögliche Änderungsvorschläge, um diese Faktoren in Zukunft zu vermeiden und Studienverhältnisse zur Untersuchung von prosozialem Verhalten von Ziegen zu verbessern.

Abstract

Prosociality describes voluntary and active behaviours by a donor providing clear benefits to the recipient. It has been extensively studied in primates but only recent studies have expanded the field of prosociality to include various other species. However, research regarding prosocial behaviours in domestic animals, especially farm animals is still rare.

This study aimed to investigate prosocial behaviours in goats, utilizing a see-saw apparatus to examine their ability to provide food prosocially to conspecifics in a group service paradigm. The experimental procedure consisted of two phases: the Learning Phase, whereby goats were taught through various stages, how to use the apparatus, and the Testing Phase, where their prosocial tendencies were assessed.

During the Learning Phase, goats had the opportunity to use the apparatus to provide treats to others and themselves. The Testing Phase was divided into three stages, with Testing Stage 1 and 3 allowing goats to provide food to others but not to themselves, and Testing Stage 2 as control stage, in which none of the goats could access the treat.

Contrary to our hypothesis, goats did not exhibit prosocial behaviours during the Testing Phase. However, the Learning Phase was also not as successful as anticipated, with only a small number of goats using the apparatus, and only two individuals demonstrating high motivation and some evidence for an understanding of how the apparatus worked. The apparatus was predominantly used to provide treats to themselves during the Learning Phase.

Several constraining factors in the study could have influenced the goats' behaviour towards the apparatus and impeded the learning process, which could explain why no prosocial behaviour towards conspecifics was observed. We further discuss how future studies could address the identified constrains and how to create more optimal conditions for studying prosocial behaviour in goats.

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1. Introduction

Prosociality encompasses many behaviours like care giving, helping, sharing, informing and teaching (Jensen, 2016). Definitions of prosocial behaviour vary throughout the literature, often depending on the field of research and focus of the study in question (Marshall-Pescini et al., 2016). While some authors use prosociality interchangeable with positive social behaviour or as the absence of negative social behaviour (Wispé, 1972), others make clear distinctions between these terms. Prosocial behaviour, compared to positive social behaviour, requires an evident benefit for the targeted individual (hereafter "receiver") and has to be an intentional and voluntary act by the individual emitting such prosocial behaviour (hereafter "donor"). The display of prosocial behaviour suggests a concern for the welfare of others and the desire to fulfil their needs (Cronin, 2012; Rault, 2019). Marshall-Pescini et al. (2016) explain that while altruism can be seen as prosocial, it demands an immediate cost for the actor, which is not a necessary requirement for all prosocial behaviours. Rault (2019) also includes behaviours that can yield some benefit for the donor or a cost for the receiver as long as it results in a net benefit for the receiver (e.g.: some forms of cooperation or honest signals of the offspring during parental care).

Due to our complex social structure, and the degree to which we extend prosocial behaviours even to strangers, prosociality was long considered to be a unique human capability (Jensen et al., 2014). Studies investigating prosocial behaviours in chimpanzees seemed to confirm this notion at first. Although they are our closest living relatives, chimpanzees did not participate in prosocial behaviour in food sharing experiments (Stevens, 2004; Gilby, 2006; Vonk et al., 2008). However, when other primates less closely related to humans were tested, they showed prosocial tendencies (Burkart and van Schaik, 2013; Burkart and van Schaik, 2020), indicating that instead of phylogenetic relatedness, prosocial tendencies might be correlated with cooperative breeding or collaborative foraging (Jaeggi et al., 2010; Burkart and van Schaik, 2013). Even though the majority of research regarding prosocial behaviour is still performed in primates (Silk and House, 2011; Burkart et al., 2014; Marshall-Pescini et al., 2016), more and more studies have started to shift their focus to investigate prosociality in other species, yielding positive results. For instance, wolves have been observed engaging in altruistic behaviour by providing food to pack members in a prosocial choice test (Dale et al., 2019). Additionally, various corvid species have shown prosocial behaviour by making food available to conspecifics in a group service paradigm (Horn et al., 2020). Another example comes from mice, where they exhibited prosocial helping behaviour by freeing constrained mice from a tube (Ueno et al., 2019).

The extension of research to other species can give us further insight into the underlying mechanisms and factors modulating prosocial behaviour and are at the centre of ongoing research (Warneken and Tomasello, 2009; Cronin, 2012). Besides kin-selection and reciprocity as ultimate explanations for the evolution of prosociality (Clutton-Brock, 2002; West et al., 2007; Brosnan and Bshary, 2010), more proximate mechanisms like empathy (Waal, 2008; Decety et al., 2016), the release of neuropeptides like oxytocin (Madden and Clutton-Brock, 2011) and the activation of brain areas involved in reward processing (Declerck et al., 2013) have been identified as contributing to the propensity to provide a benefit to others. However, prosocial tendencies are not unconditionally; an individual will not grant benefits to any other individuals. Familiarity and relationship with the receiver, dominance rank, gender of donor and receiver, previous experiences, and environmental context are also factors that can modulate the expression of prosociality (Cronin, 2012; Rault, 2019). Therefore, it is necessary to consider all these factors and mechanisms when studying prosocial behaviour.

Despite various new approaches to the study of prosociality and knowledge of prosociality growing increasingly, vast areas of prosocial behaviour have not gotten their deserved attention but bear promising potential. For example, prosociality could be used for the assessment of animal welfare (Boissy et al., 2007; Rault, 2019). To date, the implications of prosocial behaviour for animal welfare are still debated given that the circumstances in which prosociality occurs in captive animals are ambiguous and / or situational (Rault, 2019). Prosocial behaviours are usually interpreted as a sign of positive relationships between individuals and a general positive emotional state of the donor animals (Cronin, 2012; Mellor, 2015b). Further, affiliative behaviours are known to strengthen group cohesion and bonds between individuals (Boissy et al., 2007; Mellor, 2015b). Housing conditions that meet an animal's physical and psychological needs and motivations are known to promote positive social behaviours. For example, they stimulate affiliative and affectionate behaviours towards conspecifics, social play and parental care towards juveniles (Boissy et al., 2007; Mellor, 2015a). Furthermore, piglets demonstrated higher frequency of locomotor and social playing when housed in larger pre-weaning pens (Chaloupková et al., 2007). On the other hand, chronic stress and high anxiety levels are known to inhibit prosocial behaviour (Boissy et al., 2007; Ben-Ami Bartal et al., 2016), and animals living in poor housing conditions or experiencing stressful handling practices on a regular basis display few positive but heightened negative social behaviours (De-Jonge et al., 1996; Menke et al., 1999; Chaloupková et al., 2007). The expression of prosocial behaviour on a regular basis could therefore indicate a positive welfare state of the animal (Mellor, 2015b). However, one should not assume that all prosocial behaviour could act as an indicator of good welfare. Such assumptions could lead to false conclusions, given that there are indications that these behaviours can additionally act as a stress buffer and occur at higher rates after stressful and aversive events (Rault, 2012, 2019). Social animals have also been observed to engage in reconciliation after conflicts in the form of heightened affiliative behaviour and close social contact (Schino, 1998; Aureli et al., 2002; Cozzi et al., 2010). We should therefore first understand the baseline of prosocial occurrences under normal conditions in the targeted species, before making assumptions about welfare states on the basis of prosocial behaviour itself. Research regarding prosociality in domestic animals is relatively rare, and even more so in farm animals. Existing studies have limited their attention mostly to social behaviours like parental care and affiliative behaviour particularly in the context of animal welfare (De-Jonge et al., 1996; Kaminski et al., 2006; Andersen and Bøe, 2007; Chaloupková et al., 2007) but other, more complex types of prosociality, like active food sharing or helping, are yet to be investigated. To further our knowledge on prosocial behaviour in domestic animals, the objective of our study was to investigate prosocial tendencies in the domestic goat (*Capra aegagrus hircus*).

Goats were domesticated about 10,000 years ago and were probably one of the first domesticated livestock animals (Hatziminaoglou and Boyazoglu, 2004). Their ability to thrive in very rocky and meagre terrain made them especially popular in regions unfit for other livestock or agriculture and led to a widespread geographical distribution with populations on every continent except Antarctica (Dwyer, 2009). Goats are highly versatile in their food intake and spend most of their day grazing. However, if given the opportunity they prefer nutritionally dense food sources and are very selective in their food intake, only choosing preferred herbs and flowers. Hence, they are also referred to as browsers (Dwyer, 2009; Houpt, 2011; Zobel et al., 2019).

Goats are known to be very social animals, living in herds. Feral goats form matrilineal groups, so called heft groups, of two to twelve individuals consisting of females with their offspring (Dwyer, 2009; Stanley and Dunbar, 2013). Males usually form smaller separated groups although mixed-groups are also possible (Shi et al., 2005; Dwyer, 2009; Stanley and Dunbar, 2013). These groups are usually quite stable but depending on the season and the habitat, several small groups can use fission-fusion dynamics to form groups with up to 150 individuals (Shackleton and Shank, 1984; Stanley and Dunbar, 2013; Zobel et al., 2019).

Within a group, goats establish a clear social structure with a linear dominance hierarchy. The hierarchy is created through agonistic and aggressive behaviours between individuals. However, once an individual's rank is established the dominance hierarchy can remain stable over several years (Barroso et al., 2000). Age and size influence the social rank and also the presence and size of horns play a role determining the dominance rank, with larger horned and older individuals inhabiting the highest ranks in a social group (Shackleton and Shank, 1984; Barroso et al., 2000). Dominant animals control access to resources and have priority to food, mates, resting places, shade, and shelter. Higher ranking individuals also exhibit higher rates of aggression, presumably to defend their place in the hierarchy. This aggression can especially be observed in the context of feeding competition and high stocking density, manifested through greater frequency of displacement behaviour (Barroso et al., 2000; Houpt, 2011; La Miranda-de Lama et al., 2011; Górecki et al., 2020).

Although goats show higher aggression levels compared to other ruminants (Dwyer, 2009), they are also capable of forming strong social bonds with preferred social partners, which are usually of the same age and occupy a similar position in the hierarchy. Social partners engage in less agonistic behaviours and actively seek another's proximity (La Miranda-de Lama and Mattiello, 2010; Stanley and Dunbar, 2013; Górecki et al., 2020). They also show a variety of affiliative behaviours like grooming, rubbing, sniffing, close body contact, and resting together. These behaviours strengthen social bonds between individuals and the group cohesion in general (La Miranda-de Lama and Mattiello, 2010; Górecki et al., 2020).

Goats show affiliative behaviours in different situations, most of them occur when the animals are relaxed in forms of touching and resting together (Górecki et al., 2020). Affiliative behaviours are also suggested to reduce tension and aggression, and goats have been reported to engage in reconciliation after conflicts, with the previous aggressor often initiating this behaviour (Schino, 1998). Furthermore, La Miranda-de Lama et al. (2011) observed conflict resolutions, in which a dominant individual successfully managed to stop aggressive interactions between two competitors. Although dominant goats show high levels of agonistic and aggressive behaviours, higher ranking individuals receive but also exhibit most of the affiliative behaviours within a group (La Miranda-de Lama et al., 2011; Górecki et al., 2020). Aggression and affiliation can be directed at the same individuals, even though aggression frequency is lower towards affiliated social partners (Stanley and Dunbar, 2013).

Different paradigms have been established to test prosociality. The most popular of these are the prosocial choice test, helping paradigms, and food sharing tests. All of these paradigms implement different experimental set ups to identify the presence of prosocial tendencies and their underlying mechanisms (Cronin, 2012; Marshall-Pescini et al., 2016). The prosocial choice test usually lets the subject make a decision between acting prosocially, whereby both the subject and a conspecific receive a reward, or acting selfishly, where only the subject themselves is rewarded (Waal et al., 2008). Alternatively, it is also possible to design the experiment in a way, that either only a conspecific or no-one receives the reward (Dale et al., 2019). Typically, this test requires training beforehand to ensure the subjects understand the task at hand (Waal et al., 2008; Marshall-Pescini et al., 2016; Dale et al., 2019). In the helping paradigm the subject is given the opportunity to assist another individual in achieving a goal that would otherwise be unattainable, such as freeing them from a cage (Ben-Ami Bartal et al., 2014; Ueno et al., 2019), or obtaining an object that is out of reach for the other individual (Warneken and Tomasello, 2006). Prosocial choice test and helping paradigms usually test individuals in pairs with often predetermined donor-receiver dyads (Marshall-Pescini et al., 2016). In food sharing tests food items are provided to a group or prechosen pairs of individuals and observe the frequency of food transfers in relation to the subjects' relationship (Stevens, 2004; Marshall-Pescini et al., 2016).

Recently, a modified form of the prosocial choice test, called the group service paradigm, was established by Burkart and van Schaik (2013). It uses simple and intuitive experimental setups ensuring subjects can learn the task at hand. This paradigm is typically conducted within the animals' home enclosure and within their social group (Burkart and van Schaik, 2013). This allows better comparisons across studies and a variety of species, as an alternative to the primarily used prosocial choice paradigm, which appears susceptible to seemingly minor differences in methodology (Cronin, 2012; Burkart and van Schaik, 2013; Marshall-Pescini et al., 2016). By engaging with the experimental setup, subjects can provide food rewards to conspecifics, without receiving any reward for themselves (Burkart and van Schaik, 2013; Horn et al., 2020; van Leeuwen et al., 2021). The most commonly used experimental setups in the group service paradigm often involve a moving board or a see-saw apparatus. In one setup, a board must be pulled closer by an individual to let a conspecific access the reward (Burkart and van Schaik, 2013). In the other setup, an animal can step on a platform or perch to make a reward roll within reach of the receiver (Horn et al., 2016; Horn et al., 2020; Martin et al., 2021). The simplicity of this paradigm reduces criticism of possible overtraining or incomprehension that are often brought forward regarding the frequently used prosocial choice test (Marshall-Pescini et al., 2016). Additionally, since the donor cannot reward themselves, food-distraction and self-interest should not influence the donor's behaviour. This is a frequent concern in the prosocial choice test, which often allows donors to either provide food rewards for both a receiver and themselves or just to themselves (Massen et al., 2010; Marshall-Pescini et al., 2016). Moreover, the group setting allows animals to choose their partner, compared to other paradigms in which only pre-selected dyads are used. This reduces the risk of uncontrolled interrelationship modulations altering the donor's prosocial motivation and a skewed image of a species' prosociality, as the donor can choose their partner (Cronin, 2012; Marshall-Pescini et al., 2016). The study of van Leeuwen et al. (2021) highlighted the benefits of the group-service experiment in revealing prosocial behaviour in chimpanzees. The study demonstrated tendencies to act prosocially when given the opportunity to provide juice to conspecifics, even though previous studies implementing different paradigms like helping or food sharing tasks did not detect proactive prosocial behaviours in this species (Stevens, 2004; Gilby, 2006).

A recent study from 2021 (Adenot, *unpublished*) investigated whether domestic goats (*Capra aegagrus hircus*) would be able to use a food-giving see-saw apparatus and if they would show a propensity to use it to provide food prosocially to their conspecifics. The goats could provide food to others by stepping on the platform of the food-giving see-saw apparatus, which led to food rolling into a bowl on the other side of the apparatus. The study showed that dairy goats are capable of using the apparatus successfully. However, only 3 of 16 individuals used the apparatus during this study, and the number of participants was therefore too low to investigate the prosocial tendencies in goats any further. The study concluded that constraining factors of the experimental environment might have influenced the outcome of the experiment. The animals were lactating females and had only access to pasture during the same time as the experiment took place. The authors argue that these animals might have had reduced interest in the apparatus due to a preference for grazing to meet nutritional demands during this limited time. Another influencing factor could have been that dominant individuals hindered others from having access to the apparatus and from learning how it operates.

The objective of the current study was to further investigate the goats' use of the apparatus and whether their motivation to use it was to provide food to others, while also trying to avoid constrains of the previous study. Therefore, a new population and breed of goats were chosen. These goats lived in a different environment and had constant access to a grazing area. The experiment was designed to utilize the group service paradigm, which meant that while goats could provide food to their conspecifics, the donor could not access the food for themselves. During the control stage neither donor nor receiver could access the food reward. To control for an effect of order, a second test phase was included following the control phase. To ensure the goats learned how the see-saw apparatus operates, we conducted a Learning Phase prior to the actual experiment. In addition, dominance hierarchy, the social group network and affiliation index were identified to determine their potential effects on the possible donor-receiver dyads.

We hypothesised that goats are prosocial and use the food-giving see-saw apparatus to provide food treats to their conspecifics. In this context, it was predicted that the goats would use the food-giving apparatus more often when receivers have access to the reward compared with when the access to the food was blocked during the control phase.

In addition, if goats act prosocially, we wanted to further investigate if social relationships would influence the donor / receiver dyads, with the prediction that individuals are more likely to activate the apparatus and provide food for others if potential receivers are individuals with whom they have a strong social bond.

Furthermore, we predicted that the dominance rank would affect the propensity to act prosocially. Based on the effect of dominance on affiliative behaviours (Górecki et al., 2020) it was predicted that dominant goats receive but also provide more food than their lower ranking conspecifics.

2. Material and Methods

This study was conducted from the end of April to the beginning of August of 2022 in the Cumberland Wildpark in Upper Austria and was approved by the Ethics and Animal Welfare Committee of the University of Veterinary Medicine, Vienna in accordance with the University's guidelines for Good Scientific Practice (ETK-178/11/2021).

2.1 Subjects and housing

The study included 14 Nigerian dwarf goats (*Capra aegagrus hircus*) living in a single group as part of a petting zoo in the Cumberland Wildpark. The group was composed of a mixture of adults (♀=4 ♂=4) and juveniles (♀=5 ♂=1). Most animals could be distinguished by their coat colour and only two female adults had to be marked with animal marker crayon for easier identification. Adult goats were numbered from G1 to G8 and juveniles were numbered from K1 to K6.

There was no official information available regarding the subjects' family trees. However, given that the kids were still being nursed at the beginning of the study, we were able make certain assumptions about the identification of mothers and their respective kids. As such, it was presumed that G1 was the mother of K1 and K4, G3 the mother of K5 and K6 and G4 the mother of K2 and K3.

During the first weeks, two male adults (G6 and G8) were sold and were, therefore, no longer part of the study. At the same time a male adult (G7) was re-introduced to the group. This individual was present during the numbering but had been relocated to an external farm for the purpose of breeding with the goats there prior to the beginning of this study. In the middle of May, a female adult (G1) fell ill and had to be removed from the group. This led to a total of 11 subjects for the rest of the study period.

The enclosure consisted of an indoor barn area and two outdoor areas (Fig.1). One of the outdoor areas, hereafter referred to as the "petting zoo", was accessible to visitors, allowing them to enter and engage with the goats by feeding and petting them. The other outdoor area, which was fenced off from the visitors but still visible to them, served as a grazing space for the goats. This second area was utilized for the testing procedure. Goats could move freely between all three areas at any given point in time (Fig1).

The animals had access to water and hay *ad libitum* and additionally received food pellets from the park visitors.

The frequent contact and interaction of goats with park visitors is likely to have contributed to their positive responsiveness towards the experimenter. As a result, a specialized acclimation procedure was not required, as the goats readily approached the experimenter upon entering the enclosure. Prior to the start of the study, we dedicated a few hours to familiarize ourselves with the animals.

Fig. 1 **A** Diagram of the goats' home enclosure, showing the three different areas and indicating the initial location of the food-giving apparatus during the habituation and first learning stage. Letters B-D in the diagram correspond to the respective photos. **B** indoor barn area; **C** large outdoor enclosure with grazing area; **D** small outdoor enclosure and petting zoo.

2.2 Testing apparatus

For the experimental setup we utilized an apparatus (2 m × 1.25 m), as depicted in Fig 2, that had previously been piloted in a study (Adenot, *unpublished*). The apparatus consisted of a wooden platform which was connected to a see-saw mechanism (2 m). Stepping onto the platform resulted in the lifting of a pipe (0.8 m in length) to an angle, which led to a food treat, a piece of dry pasta, sliding down into a bowl. The bowl, which the goats could feed from, was 1.6 meters away from the platform. Since this study included juvenile animals, weights (5.4 kg) were added to the original see-saw apparatus to ensure that the young and much lighter animals could activate the apparatus (Fig. 2). The apparatus was designed such that a goat could step onto the platform (in this study referred to as "donor") which would provide food to a conspecific (in this study referred to as "receiver"). Surrounding the apparatus were fences, with only the bowl and the platform accessible to the goats on the outside. When the apparatus was operational, the experimenter was positioned inside the fenced-in area to replace the treat in the pipe, after the mechanism was activated. At the beginning of the study, the whole experimental setup was placed in a corner of the enclosure on the opposite side to the petting zoo, as indicated in Fig 1.

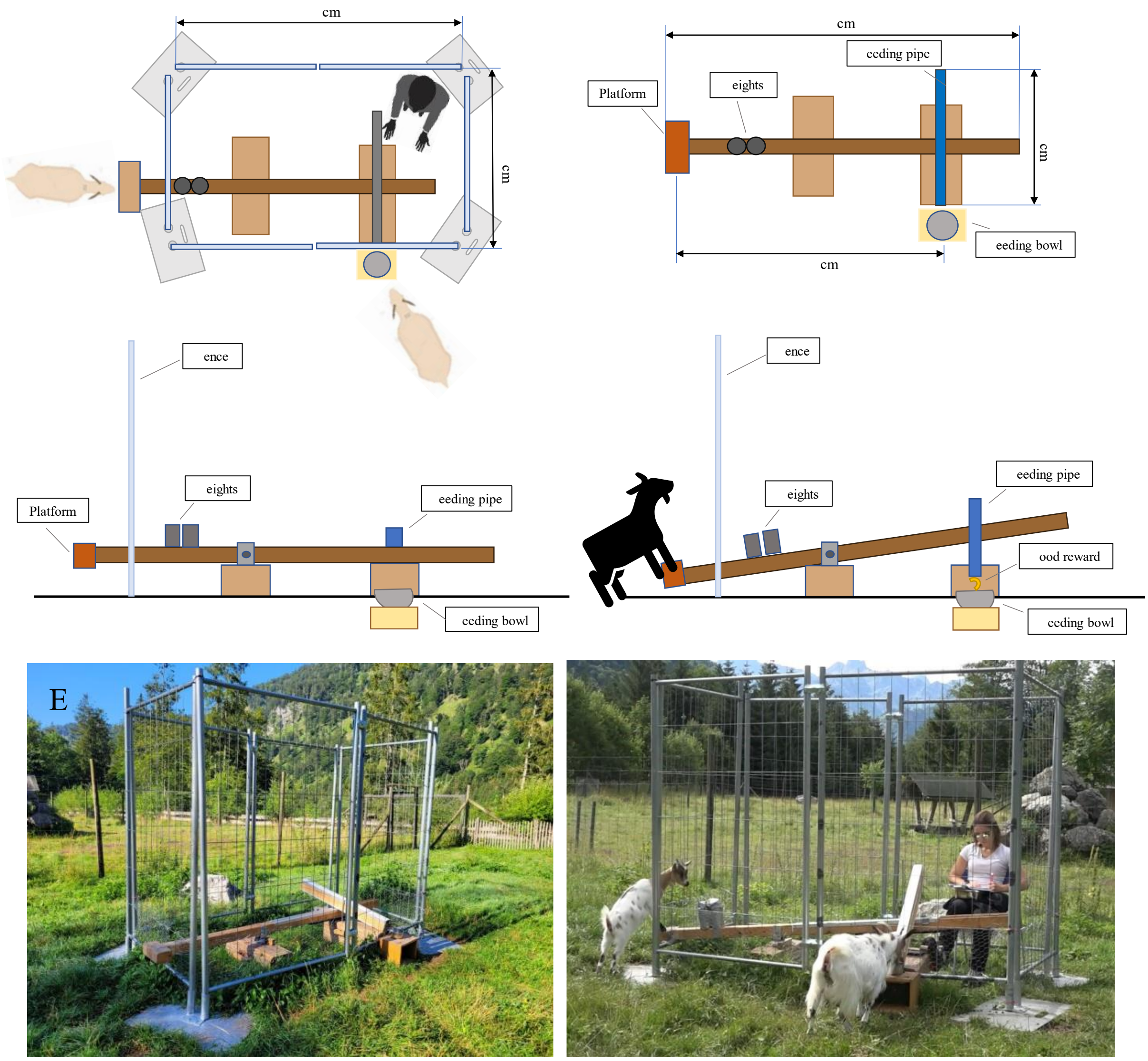

Fig. 2 Setup and see-saw apparatus. **A** Setup from above depicting the location of the see-saw apparatus, experimenter, donor and receiver goats; **B** top view of the apparatus; **C** side view of apparatus; **D** side view of apparatus with goat stepping onto the platform and food dropping into the fedding bowl; **E** photo of see-saw apparatus; **F** photo of see-saw aparatus during the experimental procedure with K4 stepping onto the platform and G2 feeding from the bowl.

2.3 Experimental Procedure

The apparatus was setup in the enclosure for 3 hours per day, separated in two 1.5-hour sessions, and 5 days per week. The study was divided into two phases. First, we conducted a learning phase followed by the testing phase (Fig. 3). The learning phase was carried out so that the goats would learn the how the apparatus works and that its use results in the provision of food pieces. The testing phase was carried out to investigate whether the goats would use the apparatus specifically to provide food to their conspecifics. Both phases were conducted in a group setting, without separating the animals.

All sessions of the habituation and learning phase and the testing phase were recorded with a camcorder.

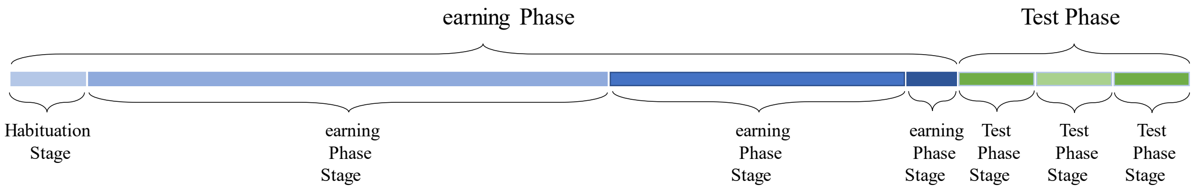

Fig. 3 Overall timeline and structure of the study

2.3.1 Learning Phase

The Learning phase was divided into 4 different stages, a habituation stage and three learning stages (Fig. 4). During these stages the goats had the opportunity to learn the mechanism of the food-giving see-saw apparatus.

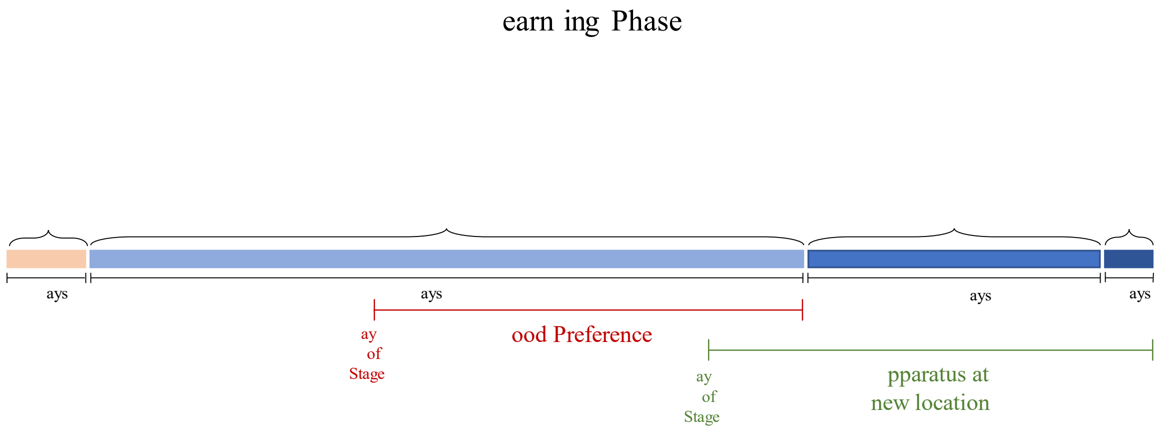

Fig. 4 Overall timeline and structure of Learning Phase.

2.3.1.1 Habituation Stage:

In the Habituation Stage, the goats were presented with the apparatus for 3 hours per day, for 4 days. This allowed the animals to habituate to the apparatus and gave them the opportunity to explore the use of it on their own. The apparatus was fully functional and food could be provided by stepping onto the platform. In this stage, the animals showed interest towards the novel object, often approaching and remaining in close proximity to the apparatus. Additionally, goats displayed sniffing at and head-rubbing behaviour against both the apparatus and its surrounding fence. However, since no relevant interaction with the apparatus took place, we moved on to the next stage.

2.3.1.2 Learning Phase Stage 1:

The aim of the first stage of the Learning Phase was for the goats to learn that food was provided in the bowl and to associate the sound of food pieces dropping into the bowl with the presence of food. Therefore, the experimenter rolled a dry pasta piece down the pipe every 5 minutes. This resulted in a distinct sound when the food hit the metal bowl. To motivate the goats to participate and indicate the start of each session, the experimenter walked through the enclosure for 5 minutes and to fed them some pieces of the food treat, by handing out individual pieces and trying to ensure each goat got at least one treat immediately before the start of the session. Goats were very motivated to receive these treats when they were handed out and gathered around the experimenter immediately as soon as they saw the treats.

After 15 days with the initial procedure of Learning Stage 1, only three goats fed from the bowl regularly, at least 2 times per day (Fig. 5). To investigate whether the lack of engagement was due to the treat type, food pellets were introduced as an alternative option. Therefore, dry pasta and animal food pellets were alternated as food treats on a daily basis, to determine whether a different food item would enhance their interest.

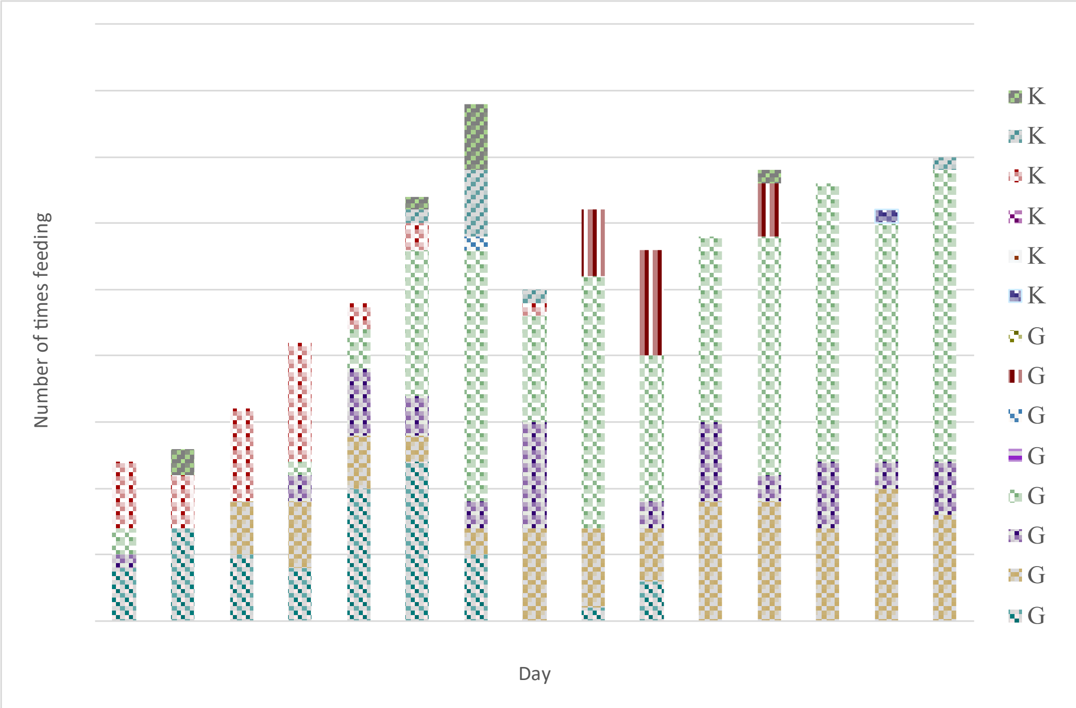

Fig. 5 Number of feedings per animal for each day of the initial 15 days of Learning Phase Stage 1.

If a goat monopolized the food and hindered other goats from feeding from the bowl, the dropping of the food was stopped until the goat stepped away and left the vicinity of the apparatus. Monopolization occurred when dominant individuals continuously occupied the area surrounding the feeding bowl and displaced lower ranking conspecifics from this area.

Although we initially planned to separate monopolizing goats from the group, to give others the chance of learning, we realised that it was not possible. The goats normally had access to all areas at any given moment and were not used to separation. Using the petting zoo as an area to divide the group could have endangered visitors but also the animals if they could not avoid unwanted interactions with the visitors. The few attempts to separate a small group into the barn area, led to a high stress response from all goats on the in- and outside of the blocked barn door, which consequently distracted even more from the experiment.

After an additional 15 days of Learning Stage 1 and alternating treats without a significant increase in the number of participating individuals (Fig. 6), we hypothesised that the see-saw apparatus might be too far away from the barn and petting zoo area, which were the areas the animals preferred to stay in the most. Therefore, we moved the see-saw apparatus to the middle of the enclosure. It was thereby in a more occupied region of the enclosure and caught more attention. Goats that would not feed from the bowl before were now able to observe the process from their usual resting place in front of the barn and subsequently started to access the food treat.

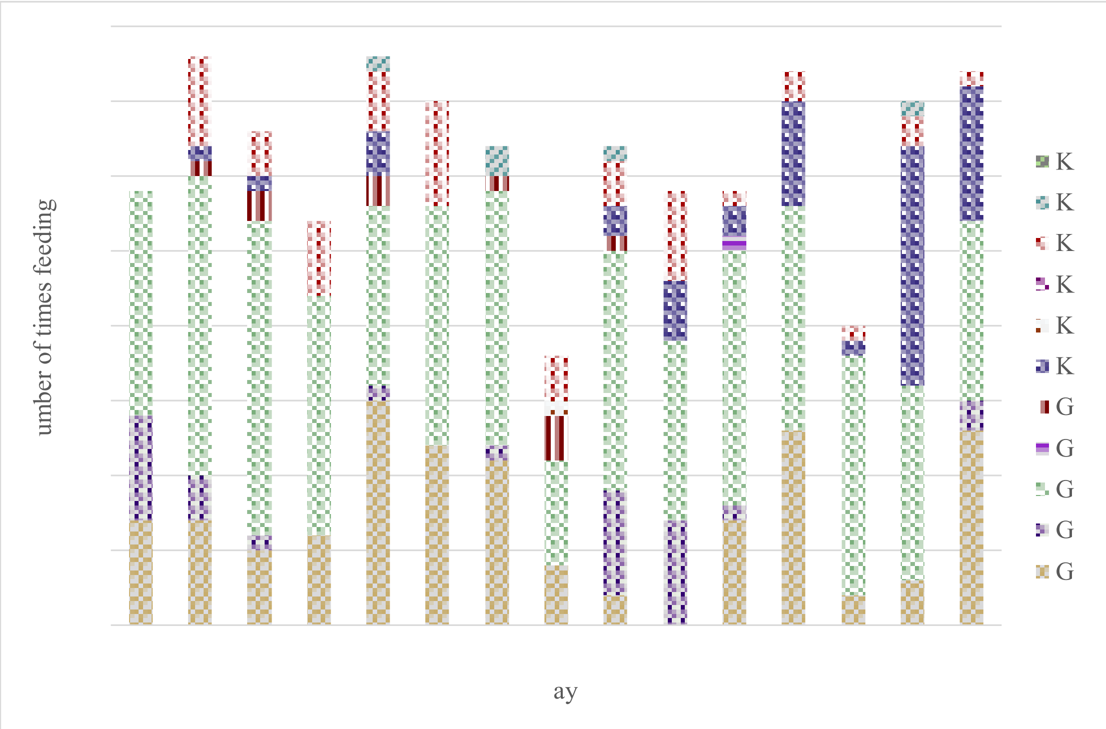

Fig. 6 Number of feedings per animal during Learning Stage 1 following 15 days after food pellets were introduced as a treat alternative to the pasta pieces, and treat type was alternated on a daily basis.

After day 37 of this stage, all but one animal fed at least once, and 6 animals fed over 10 times from the bowl in the last 5 days. This indicated that the goats had learned to associate treats with the bowl, and that we could move on to the next learning stage.

<u>2.3.1.3 Learning Phase Stage 2:</u>

In Stage 2, small branches with leaves were suspended above the platform to encourage the goats to step onto it and therefore act as a donor. Branches were sourced from hazel shrubs growing in close proximity of the goat enclosure. Stepping onto the platform resulted in lifting the pipe and a piece of pasta rolling down into the bowl. New leaves were placed above the platform every 30 minutes. If no goat stepped on the platform within 15 minutes, the experimenter rolled a food treat down the pipe into the bowl. The aim of this stage was for the goat to form an association between stepping on the platform and receiving a food treat. Due to time constraints this stage was terminated after 15 days. At this point all goats had stepped onto the platform at least once successfully. Additionally, the individual K1 exhibited a very high motivation to step onto the platform, with over 270 platform uses within one day (Fig. 7.).

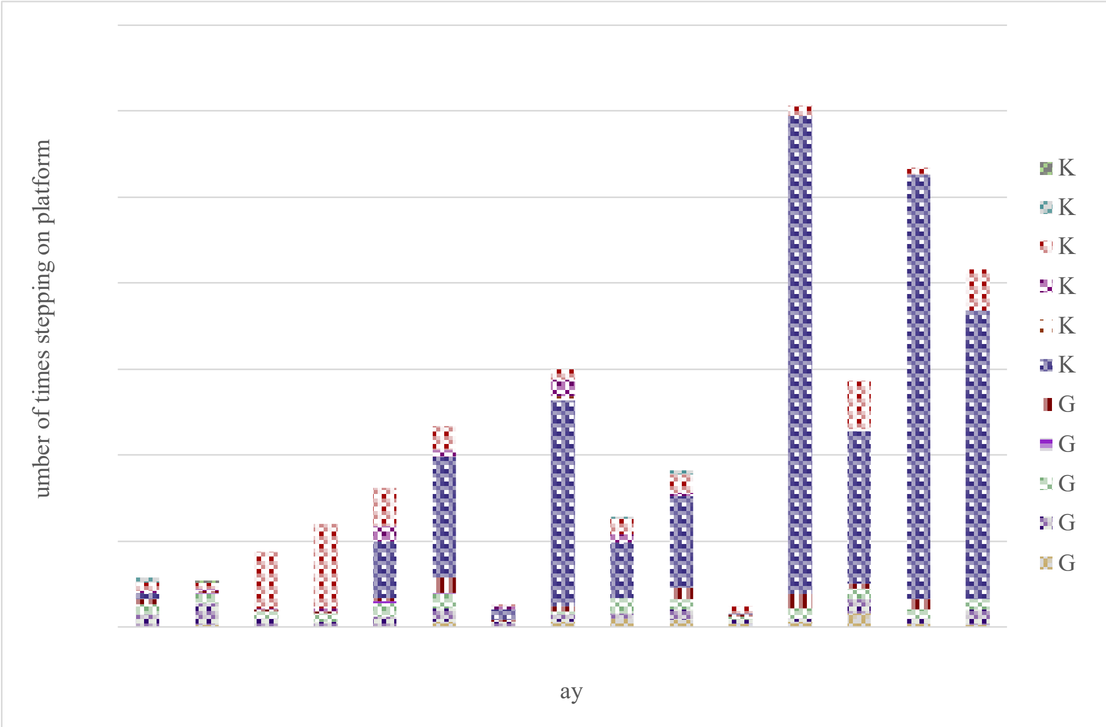

Fig. 7 Number of times goats stepped onto the platform per day during Learning Stage 2.

2.3.1.4 Learning Phase Stage 3:

In the fourth and last stage of the habituation phase the branches above the platform were removed. Our main focus was to ensure that goats understood the mechanism of the apparatus and would use the apparatus to provide food for others as well as themselves in the absence of the leaves. Due to time constraints, this stage only lasted for two days. In this time, we saw high motivation to use the apparatus in two of the juvenile goats (K1 and K4) with 76 and 49 uses on the first day and 193 and 5 uses on the second day respectively (Fig.8.).

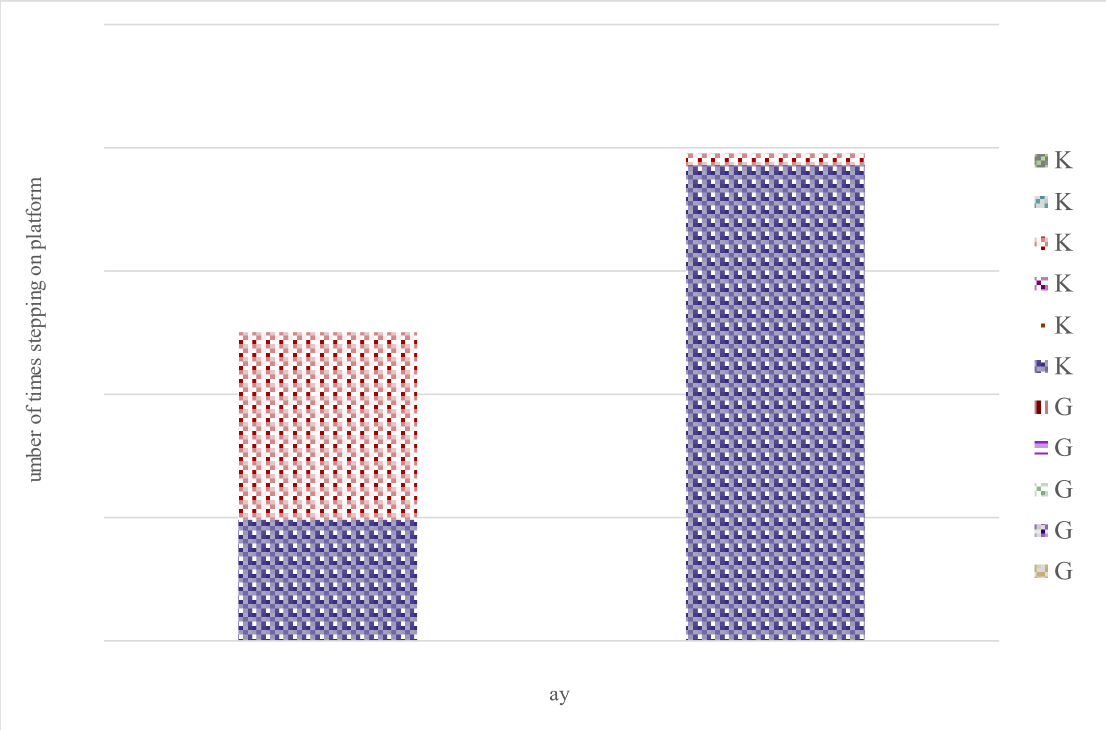

Fig. 8 Number of times stepping on the platform per animal in Learning Stage 3.

2.3.2 Testing Phase

The testing phase consisted of 3 stages with each stage lasting for 5 and a half days using Monday as the first day. In the same manner as during the habituation phase, testing took place for 3 hours per day, divided into two 1.5-hour sessions, except for the first and sixth day of each stage. On the first day, a 1.5-hour motivation phase (see below) was conducted, which reduced the experimental time to 1.5 hours. Therefore, we added an additional test day to compensate for the remaining 1.5-hours of experimental time (Fig. 7). This phase investigated whether goats would provide treats to others even if they themselves could not receive any food.

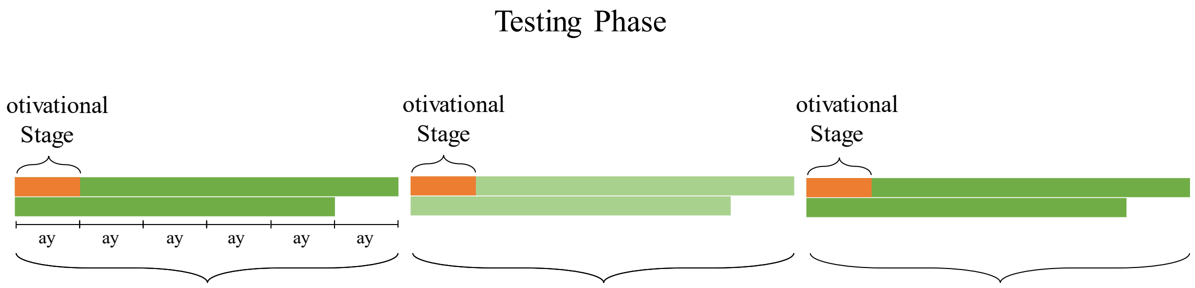

Fig. 9 Timeline and structure of the Testing Phase. Testing was split into two 1.5-hour sessions per day. Upper and lower bar depict the first, and second testing session within a day. Motivational Stage on day 1 and additional testing session on day 6 indicated.

<u>2.3.2.1 Testing Phase Stage 1:</u>

In the first testing stage a fence (2.5 m long and 1.1 m high) was placed between the donor and the receiver location, effectively preventing the goat that stepped on the platform from accessing the treat immediately. Although the fence only slowed down their access attempts, it served an important role in ensuring the donor goat would not retrieve the food for themselves. If no receiver was nearby to eat the treat, the experimenter removed the food from the bowl, reinforcing that the donor could not access the treat (Fig. 8).

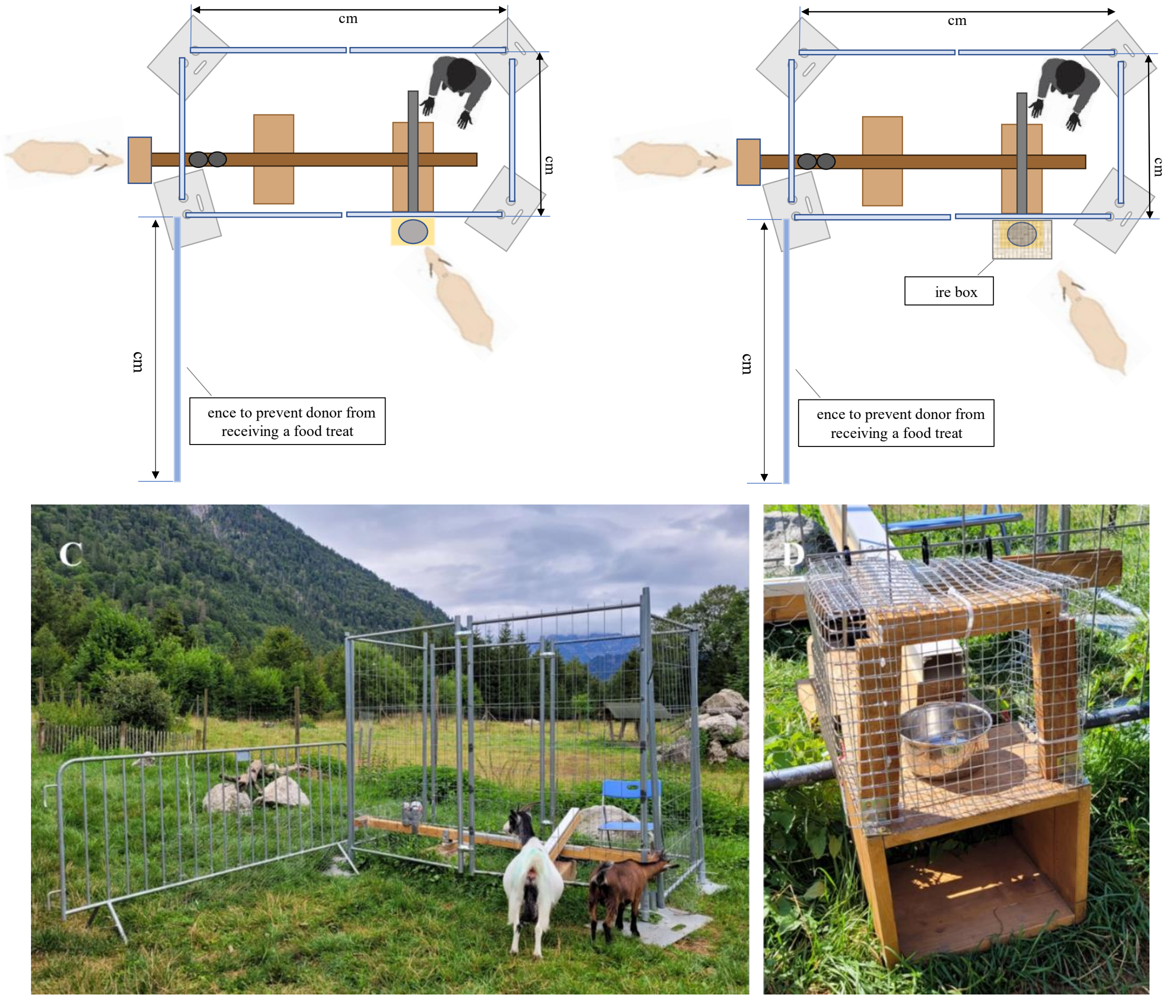

Fig. 10 Setup and see-saw apparatus during the Testing Phase. **A** Test stage 1 & 3: a fence separates the donor area from the receiver area and hinders the donor from receiving food treats for themselves; **B** Test stage 2: a wire box is placed over the food bowl to also hinder the receiver from receiving any food treats. **C** Photo of experimental setup with the fence preventing donor from receiving a food treat. The Experimenter is missing in the photo but was present during testing. **D** Photo of feeding bowl with wire box placed over it.

<u>2.3.2.2 Testing Phase Stage 2:</u>

The second testing stage started the Monday following week after first testing stage. Here, a wire box was placed over the bowl, so that food could roll into the bowl but could not be accessed by the goats. Despite the treat being inaccessible, the dropping of treat into the bowl could still be heard and seen by the goats. If goats were using the platform to provide food for others, we predicted that the frequency of stepping onto the platform should be reduced, when no one could receive the treat.

2.3.2.3 Testing Phase Stage 3:

The third testing stage took place in the week after the second stage and was identical to stage 1. This stage was added to determine whether a potential reduction of stepping on the platform in stage 2 was due to an effect of order rather than the experimental setup. If the goats stood on the platform because it resulted in food being received by other goats, we predicted that they should step less on the platform in stage 2 than in both stages 1 and 3.

2.3.2.4 Motivational Stage:

To ensure, that the goats' motivation stayed on a similar level throughout the different stages, a motivational session of 1.5-hours was conducted on the first day of each stage. This session was identical to the habituation stage 4, in which the goats could provide food for themselves by stepping onto the platform.

2.4 Behavioural Observations

In addition to the experimental procedure, live behavioural observations of the goats' social interactions were conducted. Behavioural observations were carried out and documented for later analyses to gain an insight into the dominance hierarchy and the affiliative relationships between individuals in the group. This information allowed for possible investigations on whether the dominance rank had an effect on the goats' interaction with the see-saw apparatus. Additionally, it could be used to investigate a possible influence of relationship on the donor-receiver dyads and their willingness to provide treats to each other. Depending on the weather, behavioural observations took place for either two or four hours a day, five times per week, in between the two sessions with the see-saw apparatus. Resulting in a total of approximately 191 hours. For behavioural observations continuous ad libitum sampling was conducted using the ethogram presented in Table 1.

Table 1 Ethogram for live behavioural observations adopted from Adenot (*unpublished*).

Category	Behaviour	Description
Affiliative behaviours	Sniffing	One individual sniffs another individual
	Rubbing	The donor cautiously scraped its head, horns or neck against the passive receiver's head, horns neck or body except vulva and anus, without causing the recipient withdrawal
	Lean the leg on the other animal	While standing, one individual puts its limb on the other individual (usually laying down)
	Lean against each other	A goat leans or rests its head/bottom jaw against any part of the body of another goat without causing its withdrawal
	Grooming	The donor uses its tongue, lips or teeth to scrape, lick or nibble the head or body, except vulva and anus, of the recipient without causing withdrawal
	Play fight	Two goats simulate a fight without causing withdrawal of one of the goats; often accompanied by other affiliative behaviours like grooming and rubbing.
Agonistic/aggressive behaviours	Non-physical displacement	Any non-physical interaction in which one goat (the winner) causes a conspecific (the loser) to withdraw
	Physical displacement	Any physical interaction in which one goat (the winner) causes a conspecific (the loser) to withdraw

Furthermore, scan samples to determine the individuals in proximity to each goat were conducted every 15 minutes during the behavioural *ad libitum* observations. During the scan, individuals with direct body contact and the nearest neighbouring individual, and all individuals within one body length to each goat were documented. The proximity of the goats to each other for the scan samples, as well as affiliative and agonistic behaviours during the behavioural observations were scored live by the experimenter.

2.5 Data and statistical analysis

All stages of the experimental procedure were filmed with a camcorder and videos were analysed using the "Behavioural Observation Research Interactive Software" (BORIS v. . . -2022-10-05). During the analysis several behaviours were documented, which are listed in the ethogram of Table 2, and the identities of the subjects performing these behaviours were monitored.

Table 2 Ethogram for observation of interaction with the see-saw apparatus.

Behaviour	Type	Description
Stepping onto the platform	Event	Subject steps onto the platform and successfully activates the see-saw apparatus
Feeding from the bowl	Event	Subject eats the treat in the bowl
Duration of proximity to the platform	Duration	Duration the subject is within 1.5 body lengths of the platform
Duration of proximity to bowl	Duration	Duration the subject is within 1.5 body lengths of the feeding bowl

ll st atistical analysis and models were conducted with RStudio (version . . . " Ghost Orchid", RStudio Team) using the R statistical software (version . . . "Klick Things", R Core Team 2021). Packages and functions used for each analysis are described below. The significance level was set to α = . .

2.5.1. Dominance rank

To determine the dominance hierarchy in the group, we calculated the Normalised David Score (NormDS), which provides a measure of a subject's dominance rank within the group.

First, we created a matrix based on the observed agonistic interactions among the individuals during the continuous behavioural observations. Each row and column represented an individual and the values in the matrix indicated the number of agonistic interactions between each pair of individuals.

By using the “get orm   S” function with the “ ij” method from the “steepness” package (version 0.3-0, Leiva and de Vries, 2022) we calculated the NormDS. The method of Dij is a specific algorithm to normalize the raw David Score which represents the sum of victories minus the defeats for each subject while considering all pairwise interactions. The normalization ensures that the values are both comparable and easily interpretable, representing the relative dominance ranks among individuals. Higher NormDS values indicate a higher dominance rank within the group.

2.5.2 Effect of Learning Stage and modification on interaction with the see-saw apparatus

During the Learning Phase multiple stages and modifications of the experimental setup were introduced with the aim that goats would learn the mechanisms of the see-saw apparatus.

The impact of the different stages of the Learning Phase and the various modifications on the goats’ interaction with the see-saw apparatus was investigated. These modifications included the two different treat types of pasta and pellets, the location of the apparatus before and after the movement of the see-saw apparatus and the presence or absence of leaves during the Learning Stages 2 and 3. Measures of interaction, such as the frequency of stepping onto the platform, frequency of feeding form the bowl, proportion of time spent in proximity to the bowl, and proportion of time spent in proximity to the platform were examined. Additionally, the variables of day, sex and NormDS as an indicator of dominance rank, were included in the analysis as control predictors to assess if they had influence on the behaviours. For the stages of Learning Phase and each of the modifications, a separate GLMM was conducted to investigate their effect on each interaction measure.

<u>2.5.2.1 Frequency of feeding and stepping onto the platform</u>

The models investigating the impact of modification on the interaction measures of frequency were largely similar, primarily differing in terms of the variables of frequency of feeding and frequency of stepping onto the platform, as well as the specific modification being analysed.

To analyse the effect of modification on the frequency goats fed from the bowl and the frequency of times the goats stepped onto the platform a GLMM with a Poisson distribution error was employed, utilizing the “glmer” function of the “lme ” package (version 1.1-32, Bates et al., 2015). The Poisson family as the distribution error was used based on the count nature of the response variable. Depending on the analysis the response variable was either the number of times goats fed from the bowl or the number of times goats stepped onto the platform. The specific modification was included as a fixed effect, additionally to the fixed effects of the variables of day, sex and NormDS and an interaction between modification and day. Day and modification were included as random slopes and subject identity was included as the random effect to consider subject-specific variations in frequency. To account for differences in observation times, the model also incorporated the offset term of the log-transformed total duration of observation. Details for each individual model will be described below.

Prior to fitting the model, the data was prepared for analysis by summarizing all observations per day. This step was necessary due to partially different observation numbers per day. The data was grouped based on the variables “day”, “subject”, “sex” and “ or m S ” using the “summarise” function from the “dplyr” package (version . . , Wickham et al., 2023). This allowed us to combine the total duration of observation and number of feeding and platform per individual per day.

Furthermore, random slopes were identified and the factors used as random slopes were dummy coded and centred. The covariates day and NormDS were z-transformed to a mean of zero and a standard deviation of one to allow for an easier interpretation of results and better model convergence and were then included as fixed effects or as random slopes. To ensure an optimized fitting process and better convergence of the models, the “glmerControl” function of the “lme ” package (version . -32, Bates et al., 2015) was used to implement control parameters. The “bobyqa” optimizer was applied and the control argument “optCtrl” was set to a maximum of 100 000 function evaluations.

Overdispersion of the models were assessed using a function kindly provided by Roger Mundry, and collinearity among the fixed effects was assessed by utilizing the the “vif” function from the “car” package (version . -2, Fox and Weisberg, 2019) and applied it to a linear regression model using the response variable and fixed effects of the GLMM without the interaction of fixed effects.

To estimate the overall effect of the fixed effects on the response variable, the full model was compared to a null model. The null model retained all specifications of the full model, while excluding the fixed effects of the variables of interest. A likelihood ratio test (Chi-square test) using the "anova" function with the argument "test" set to "Chisq" was performed, which revealed the fit of the full model.

<u>Effect of Learning Stage on the frequency of feeding:</u>

To determine the impact of Learning Stage, day, sex and dominance rank on the feeding frequency of subjects, a GLMM with a Poison distribution error (version 1.1-32, Bates et al., 2015) was employed as described above.

The initial model revealed high estimates for the fixed effects of Intercept (estimate: -9.3492, SE: 0.2991, $p < 0.001$) and Learning Stage 3 (estimate: 5.6505, SE: 1.7948, $p < 0.001$) and was overdispersed (dispersion parameter = 3.45). In order to enhance the model, an additional random effect variable of "observation" was added, which improved the estimate for the fixed effect of Learning Stage 3. This model exhibited underdispersion (dispersion parameter = 0.308), however, after trying multiple variations of this model without any improvement, the decision was made to proceed with this model. To assess collinearity among the fixed effects the "vif" function from the "car" package (version . -2, Fox and Weisberg, 2019) was utilized. The variance inflation factor analysis revealed no evidence of collinearity (max. VIF= 1.1494)

<u>Effect of Learning Stage on the frequency of stepping onto the platform:</u>

To determine the effect of Learning stage, day, sex and dominance rank on the frequency of goats stepping onto the platform, a GLMM with a Poison distribution error (version 1.1-32, Bates et al., 2015) was employed as described above.

The initial model was highly overdispersed (dispersion parameter = 6.909). An additional random effect variable of "observation" was added in an attempt to improve the model. The resulting model was underdispersed (dispersion parameter = 0.349) and had high estimates for the intercept (estimate = 14.6420, SE = 1.0615, $p <0.001$) and Learning Stage 3 (estimate = -11.1049, SE = 14.0696, $p = 0.4299$). After trying various variations of this model by removing the correlations, random slopes, the random effect of observation or a combination of these, which only resulted in either high estimates or great overdispersion, a model was chosen that excluded random slopes and included the random effect of observation. This model had an acceptable dispersion (dispersion parameter = 0.7416) and the variance inflation factor analysis, obtained by utilizing the "vif" function from the "car" package (version . -2, Fox and Weisberg, 2019), revealed no evidence of collinearity (max. VIF= 1.149).

<u>Effect of treat on the frequency of feeding:</u>

In this analysis the impact of the two different food treats, that were used during the informal food preference test, on the frequency goats fed from the bowl was investigated. The dataset only included observations from day 16 to 37 of the first Learning Stage, when the two treats of pasta and pellets were used. A general linear mixed model with a Poisson error distribution (version 1.1-32, Bates et al., 2015) as described above was fitted, with the response variable as the number of times feeding and the specification of "treat" as the fixed effect.

The original model showed correlations close to between the random slope variable "treat" and the random effect variable "subject", indicating they were unidentifiable. Consequently, it was decided to eliminate these correlations from the model. By using a function kindly provided by Roger Mundry, an overdispersion (dispersion parameter = 1.413) was detected in the new model. To enhance the model further, an additional random effect variable of "observation" was added, which significantly improved the dispersion (dispersion parameter = 0.564). Collinearity of fixed effects was assessed by applying the variance inflation- factor analysis ("car" package, version . -2, Fox and Weisberg, 2019), similarly to the previous analysis, which revealed no issues of collinearity (max. VIF = 1.1793)

The null model excluded the fixed effect of treat, but retained otherwise all specifications of the full model.

<u>Effect of location on the frequency of feeding:</u>

In this analysis, it was aimed to examine the impact of the location on the frequency goats fed from the bowl. The dataset consisted of an equal number of observations collected both before and after the change of location of the apparatus, during Learning Stage 1. This ensured a comprehensive analysis of the effects of location change on the observed variables. The GLMM was fitted with Poisson distribution error (version 1.1-32, Bates et al., 2015) as described above with the number of times feeding as the response variable and location as a fixed effect.

The initial model was overdispersed (dispersion parameter = 1.462) and showed correlations close to between the random slope of the variable "location" and the random effect variable "subject". Therefore, the correlations were removed which resulted in an improved but still overdispersed model (dispersion parameter = 1.398). To further improve the model, an additional random effect variable of "observation" was added, which resulted in a significantly better dispersion (dispersion parameter 0.508). Collinearity of fixed effects was assessed by applying the variance inflation- factor analysis ("car" package, version . -2, Fox and Weisberg, 2019), which revealed no issues of collinearity (max. VIF = 1.238).

The null model used in the likelihood ratio test excluded the fixed effect of location, but retained otherwise all specifications of the full model.

Effect of leaves on the frequency of feeding:

To assess the influence of the presence or absence of leaves on the frequency goats fed from the feeding bowl, a GLMM with a Poisson distribution error (version 1.1-32, Bates et al., 2015) was employed as described above. The dataset consisted of the last two days of Learning stage 2 (in which the leaves were present) and the 2 days of Learning Stage 3 (leaves were removed). This ensured the same number of observations and a comprehensive analysis of the effects of location change on the observed variables. The response variable was defined as the number of times feeding from the bowl and "leaves" was added as a fixed effect.

Overdispersion (dispersion parameter = 4.828) in the original model was identified by using a function kindly provided by Roger Mundry. To address this issue, the new random effect variable "observation" was added, which represented each individual observation. The resulting model exhibited underdispersion (dispersion parameter = 0.311). In an attempt to improve the model, the random slopes were. However, this led to even greater underdispersion (dispersion parameter = 0.281). Therefore, the previous model was ultimately chosen with the random effect "observation" and random slopes. The collinearity of fixed effects was assessed by applying the variance inflation- factor analysis ("car" package, version . -2, Fox and Weisberg, 2019) which revealed no issues of collinearity (max. VIF = 1.179).

The null model used in the likelihood ratio test excluded the fixed effect of leaves, but retained otherwise all specifications of the full model.

2.5.2.1 Proximity to feeding bowl and platform

The models investigating the impact of modification on the interaction measures of proximity were largely similar, primarily differing in terms of the variables of proportion of time spent in proximity to the feeding bowl and proportion of time spent in proximity to the platform, as well as the specific modification being analysed.

To analyse the effect of modification on the proportion of time goats spent in proximity to the feeding bowl and the proportion of time spent in proximity to the platform a GLMM with a beta distribution error and a logit link function was fit, utilizing the "glmmTB" function from the "glmmTB" package (version . . , Brooks et al., 2017). This model had similarities to the model for frequency of feeding and stepping onto the platform. In this case the response variable was either the proportion of time spent in proximity to the feeding bowl or the proportion of time spent in proximity to the platform. Fixed effects, random slopes and random effect were the same as in the previous models. Details for each model will be described below.

Prior to fitting the model, the data was prepared in a similar manner to the analysis of frequency of feeding and stepping onto the platform by summarising the data, identifying random slopes, dummy coding and centering the variables used as random slopes and z-transforming the covariates day and NormDS. Since the data contained at least one zero and beta models like utilized here cannot handle zeros and ones, the response variable "proportion of time" we transformed by using the following formula ("x" represents the variable that needs to be transformed):

$$\text{Transformed x} = \frac{x*(\text{length}(x)-1)+0.5}{\text{length}(x)}$$

Dispersion of the models were assessed by using a function kindly provided by Roger Mundry, and collinearity among the fixed effects was assessed by utilizing the the "vif" function from the "car" package (version . -2, Fox and Weisberg, 2019) and applied it to a linear regression model using the response variable and fixed effects of the GLMM without the interaction of fixed effects.

To estimate the overall effect of the fixed effects on the response variable, the full model was compared to a null model. The null model retained all specifications of the full model, while excluding the fixed effects of the variables of interest. A likelihood ratio test (Chi-square test) using the “anova” function with the argument “test” set to “Chisq” was performed, which revealed the fit of the full model.

Effect of Learning Stage on the proportion of time in proximity to the feeding bowl:

To investigate the influence of Learning Stage, day, sex and dominance rank on the proportion of time spent in proximity to the bowl, a GLMM with a beta distribution error and a logit link function (“glmmTB” package version . . , Brooks et al., 2017) was employed as described above. The response variable was defined as the transformed proportion of time in proximity to the bowl and the variable “stage” was added as a fixed effect.

While fitting the initial model a convergence error was encountered, along with a correlation close to (.) between the random slope variable “day” and the random effect variable “subject”. Consequently, these issues were addressed by removing the correlations and evaluating the dispersion by using a function kindly provided by Roger Mundry, yielding a dispersion parameter of 0.943. Further, collinearity among the fixed effects was assessed, without detecting any issues (max. VIF = 1.149).

The null model used in the likelihood ratio test excluded all fixed effects, but retained otherwise all specifications of the full model.

Effect of Learning Stage on the proportion of time in proximity to the platform:

To investigate the influence of Learning Stage, day, sex and dominance rank on the proportion of time spent in proximity to the bowl, a GLMM with a beta distribution error and a logit link function (“glmmTB” package version . . , Brooks et al., 2017) was employed as described above. The response variable was defined as the transformed proportion of time in proximity to the bowl and the variable “stage” was added as a fixed effect.

While fitting the initial model a convergence error was encountered, along with a correlation close to between the random slope variable “ e arning Stage ” and the random effect variable “subject”. Consequently, the correlations between random slopes and random effects were excluded from the model. This model exhibited an overdispersion (dispersion parameter = .) . In an attempt to improve the model, a new random effect variable “observation” was added, resulting in a slight improvement of the dispersion (dispersion parameter = 1.212). Further attempts to enhance the model by removing the random slopes, did not improve the dispersion parameter (dispersion parameter = 1.258). Therefore, with the previous model was chosen.

Collinearity of fixed effects was assessed by applying the variance inflation- factor analysis ("car" package, version . -2, Fox and Weisberg, 2019), which revealed no issues of collinearity (max. VIF = 1.149)

The null model used in the likelihood ratio test excluded all fixed effects, but retained otherwise all specifications of the full model

<u>Effect of the treat on the proportion of time in proximity to the feeding bowl:</u>
To investigate the impact of the two different food treats, that were used during the informal food preference test on the proportion of time spent in proximity to the feeding bowl a GLMM with a beta error distribution and logit link function was fitted as described above ("glmmTB" package version 1.1.7, Brooks et al., 2017). The response variable was the transformed proportion of time of the proximity to the bowl and "treat" as the fixed effect. The dataset only included observations from day 16 to 37 of the first Learning Stage, when the two treats of pasta and pellets were used.

As with the previous models, convergent issues were encountered while fitting the model and a correlation close to between random effect variable "subject" and random slope variable "treat" (.) was identified. To address these issues, the correlations were excluded from the model and the dispersion was evaluated by using a function kindly provided by Roger Mundry, yielding a dispersion parameter of 1.022. The variance inflation factor analysis, was obtained by utilizing the "vif" function from the "car" package (version . -2, Fox and Weisberg, 2019) and revealed no evidence of collinearity (max. VIF= 1.179).

The null model used in the likelihood ratio test excluded the fixed effect of treat, but retained otherwise all specifications of the full model.

<u>Effect of location on the proportion of time in proximity to the feeding bowl:</u>
In this analysis, aimed to examine the impact of the location on the proportion of time in proximity to the feeding bowl. The dataset consisted of an equal number of observations collected both before and after the change of location of the apparatus, during Learning Stage 1. This ensured a comprehensive analysis of the effects of location change on the observed

variables. The GLMM was fitted with the beta distribution error and logit link function as described above ("glmmTB" package version . . , Brooks et al., 2017). The transformed proportion of time in proximity to the feeding bowl was used as the response variable and the fixed effect "location" was the specification of the model.

Since this model encountered convergent issues, the same approach as in the previous analysis was followed and the correlations between random slopes and random effects were removed even though the correlation themselves would have been acceptable. The dispersion of the model (dispersion parameter = 1.101) was assessed and the variance inflation factor analysis revealed no evidence of collinearity (max. VIF= 1.238).

The null model used in the likelihood ratio test excluded the fixed effect of location, but retained otherwise all specifications of the full model.

<u>Effect of leaves on the proportion of time in proximity to the feeding bowl:</u>

To investigate the influence of the presence or absence of leaves on the proportion of time goats spent in proximity to the bowl, a GLMM with a beta distribution error and a logit link function ("glmmTB" package version . . , Brooks et al., 2017) was employed as described above. The response variable was defined as the transformed proportion of time in proximity to the bowl with the fixed effect of "leaves" as the specification of this model. The data set was adjusted in the same way as in the analysis of effect of leaves on the frequency of feeding.

The model showed convergence issues, which led to the decision to exclude the correlations between random slopes and random effects, even though the correlations were considered acceptable. The dispersion of the model was assessed by utilizing a function kindly provided by Roger Mundry and found a slight but acceptable overdispersion (dispersion parameter = .) . The variance inflation factor analysis, was obtained by utilizing the "vif" function from the "car" package (version . -2, Fox and Weisberg, 2019) and revealed no evidence of collinearity (max. VIF= 1.179).

The null model used in the likelihood ratio test excluded the fixed effect of leaves, but retained otherwise all specifications of the full model.

<u>Effect of modification “leaves” on the proportion of time in proximity to the platform:</u>
To investigate the influence of the presence or absence of leaves on the proportion of time goats spent in proximity to the platform, a GLMM with a beta distribution error and a logit link function (“glmmTB” package version . . , Brooks et al., 2017) was employed as described above. The response variable was defined as the transformed proportion of time in proximity to the platform with the fixed effect “leaves” as the specification of this model. The data set was adjusted in the same way as in the analysis of effect of leaves on the frequency of feeding.

While fitting this model encountered a convergence issue and correlations close to -1 (-0.987) between the random effect variable “subject” and the random slope variable “day” were encountered. This led to the decision to exclude the correlations between random slopes and random effects. The dispersion of the model was assessed by utilizing a function kindly provided by Roger Mundry and found no dispersion issues (dispersion parameter = 1.036). The variance inflation factor analysis revealed no issues with collinearity (max. VIF= 1.179).

The null model used in the likelihood ratio test excluded the fixed effect of leaves, but retained otherwise all specifications of the full model.

2.5.3 Probability of providing food to others compared to one-self during the Learning Stages

To investigate the probability of goats engaging in prosocial food-sharing behaviour with conspecifics during the Learning Stages a GLMM with a binomial distribution error was employed by applying the “glmer” function of the “lme ” package (version . -32, Bates et al., 2015). The binomial error distribution was chosen to fit the binary nature of the response variable “receiver”, which was categorised into “self” (coded as) and “other” (coded as), implying if the goat provided food to themselves or a conspecific. Additionally, the GLMM allowed us to assess the relationship between the receiver and the fixed effects of day and dominance rank of the donor. The donor identity was added as a random effect.
Prior to fitting the model, the covariates day and NormDS were z-transformed before their inclusion as fixed effects. To ensure an optimized fitting process and better convergence, the “glmerControl” function of the “lme ” package (version . -32, Bates et al., 2015) was used to implement control parameters. The “bobyqa” optimizer was applied and the control argument “optCtrl” was set to a maximum of f unction evaluations.

The model was assessed for overdispersion by using a function kindly provided by Roger Mundry, which revealed no dispersion issues (dispersion parameter = 0.957).

A likelihood ration test for a full-null model comparison was conducted by applying the “anova” function with the argument “test” set to “Chisq”. The null model was derived from the full model by removing the fixed effects while maintaining other specifications.

2.5.4 Engagement with platform during Testing Stage

To investigate the effects of stage and test day on the frequency goats stepped onto the platform during the testing phase, a GLMM with a Poisson distribution error was employed, utilizing the “glmer” function of the “lme ” package (version . -32, Bates et al., 2015). The response variable was defined as the number of times goats stepped on the platform with fixed effects for stage (testing stage 1, testing stage 2 and testing stage 3) and test day (1, 2, 3, 4, 5, 6), including an interaction between stage and test day. Subject identity was included as the random effect to account for subject-specific variations in platform stepping behaviour. Additionally random slopes were included for test day and stage. To account for differences in observation times, the model also incorporated the offset variable of the log-transformed total duration. Before fitting the model, the data was prepared in a similar way as in the previous analysis of effect on frequency of feeding and stepping onto the platform, by summarising the data of observations per day, identifying and dummy coding and centering random slopes. The covariate test day was z-transformed before its inclusion as a fixed effect or as a random slope. To ensure an optimized fitting process and better convergence, the “glmerControl” function of the “lme ” package (version . -32, Bates et al., 2015) was utilized to implement control parameters. The “bobyqa” optimizer was applied and the control argument “optCtrl” was set to a maximum of 100.000 function evaluations.

The correlations between the random slopes and random effects for the third test stage were close to -1 indicating that it was unidentifiable. Therefore, the correlations were removed from the model. The presence of collinearity within the fixed effects was assessed, indicating that there were no collinearity issues (VIF max. 1). The model was assessed for overdispersion, utilizing a function kindly provided by Roger Mundry, which revealed a slight underdispersion (dispersion parameter = 0.513).

As in the previous models the full model was compared to a null model, using a likelihood ratio test (Chi-square test) utilizing the "anova" function with the argument "test" set to "Chisq". The null model retained all specifications of the full model, while excluding all fixed effects.

Additionally, to get a better understanding of the relationship between Testing Stage 2 and 3, the variable "stage" was restructured and Testing Stage wa s selected as the new reference level. The same model as previously was chosen for this analysis, which did not show any dispersion issues (dispersion parameter = 0.812). Another full-null model comparison was conducted to assess the fit of the full model.

3. Results

3.1 Effect of Learning Stage and modification on interaction with the see-saw apparatus

3.1.1 Frequency of feeding and stepping onto the platform

Effect of Learning Stage on the frequency of feeding:

The full model investigating the effect of stage on the frequency of feeding differed significantly from the null model (full-null model comparison: $\chi^2 = 32.87414$, df= 7, $p < 0.001$). The model indicated no significant effect of interaction between the stages of the Learning Phase and the day on the frequency of feeding. The interaction was therefore removed from the model, which also resulted in a significant better fit for the full model (full-null model comparison: $\chi^2 = 31.583$, df = 5, $p < 0.001$) (Table S 5).

The model showed, a significant positive effect of Learning Stage 2, when small branches with leaves were suspended above the platform, (estimate = 2.103, SE = 0.6364, $p < 0.001$) on the frequency of feeding, while Learning Stage 3, when the branches were removed, did not differ from Learning Stage 1 (estimate = 1.415, SE = 0.9224, p = 0.125) (Fig. 1), (Table S 6).

Sex had a significantly negative effect on the frequency of feeding, with male subjects showing lower feeding levels compared to their female conspecifics (estimate = -2.3765, SE = 0.4202, $p < 0.001$). Furthermore, a significant positive effect of z.NormDS (estimate = 0.9599, SE = 0.1821, $p < 0.001$) could be found, indicating that subjects higher in the dominance hierarchy displayed a higher feeding frequency (Table S 6).

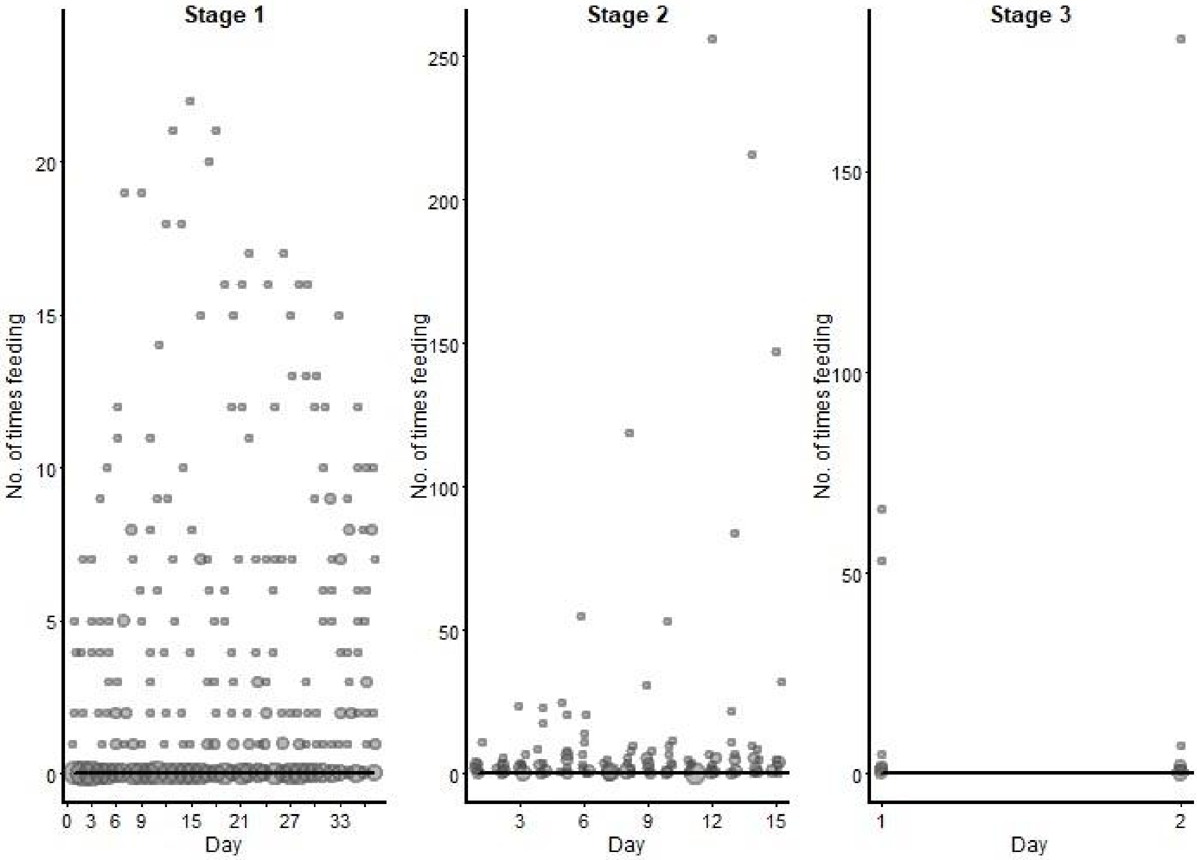

Fig. 11 Number of feeding uses per day across the three learning stages. Each plot shows the observed feeding events long the solid line representing the fitted model and the shaded line representing its 95% confidence intervals. Confidence band is very narrow. Size of the data point is proportional to the number of observations with that value. Note that the y-axis scale varies between the plots.

<u>Effect of Learning Stage on the frequency of stepping onto the platform:</u>

The full model investigating the effect of stage on the frequency of stepping onto the platform differed significantly from the null model (full-null model comparison: $\chi^2 = 251.33$, df = 7, $p < 0.001$) (Table S 7).

The model indicated a significant positive effect for the interaction of Learning Stage 2 and day (estimate = 1.143, SE = 0.4269, p = 0.007), but no significant effect for the interaction of Learning 3 and day (estimate = -2.4603, SE = 9.1823, p = 0.789). This shows that goats increasingly stepped onto the platform as the Learning Stage 2 progressed, whereas no such effect could be seen in Learning Stage 3. There was also a significant positive effect of Learning Stage 2 (estimate = 5.4066, SE = 0.3811, p < 0.001) indicating a general higher frequency of stepping on the platform and a significant negative effect of day (estimate = -0.6894, SE = 0.2858, p = 0.016) (Fig. 2), (Table S 8).

The variable of sex had a significant negative effect (estimate = -2.5417, SE = 0.9941, p = 0.016), with male subjects stepping less frequently on the platform than their female conspecifics (Table S 8).

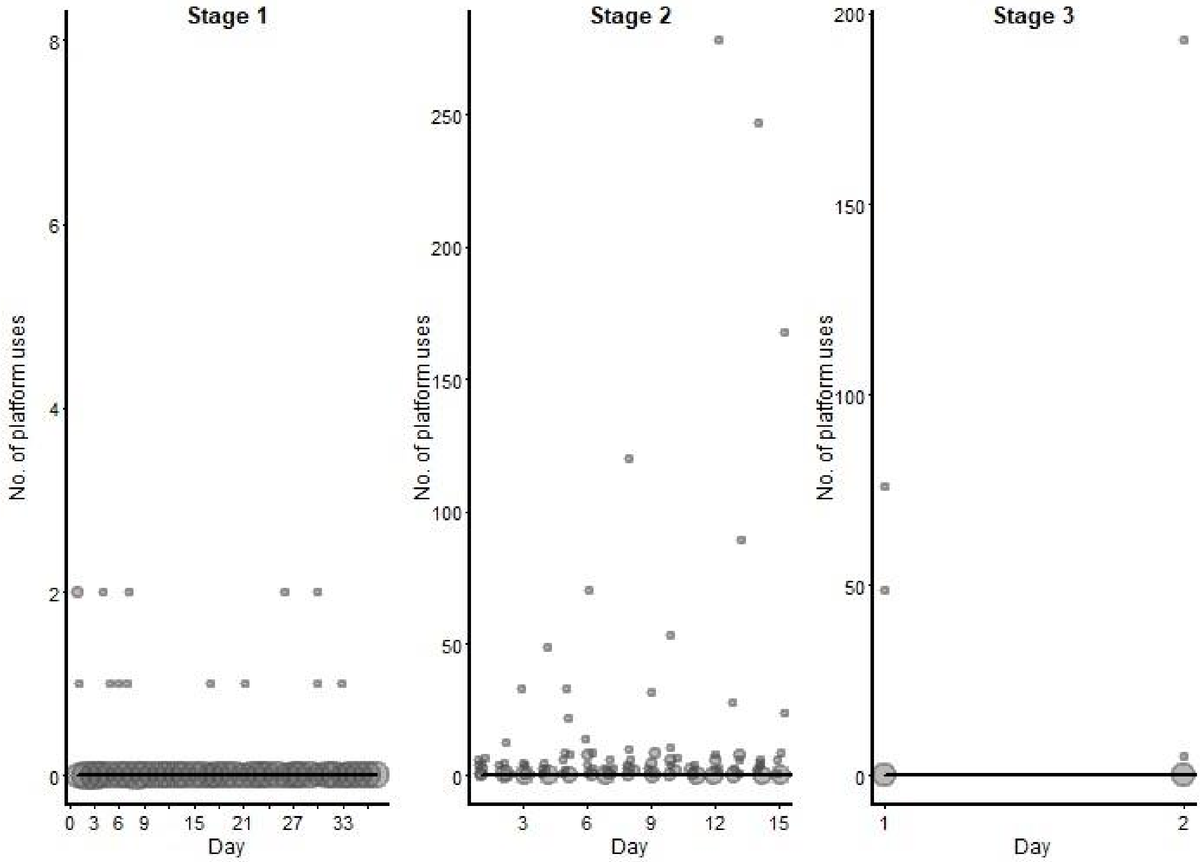

Fig. 12 Number of platform uses per day across the three learning stages. Each plot shows the observed platform events long the solid line representing the fitted model and the shaded line representing its 95% confidence intervals. Confidence band is very narrow. Size of the data point is proportional to the number of observations with that value. Note that the y-axis scale varies between the plots.

Effect of treat on the frequency of feeding:

The full model to investigate the effect of the treat on the effect of feeding did not show a significant better fit compared to the null model (full-null model comparison: $\chi^2 = 0.4868$, df = 2, p = 0.783). Indicating that there was no significant difference of feeding frequency between the two treat types that were presented.

Effect of location on the frequency of feeding:

The full model to investigate the effect of the location on feeding frequency did not show a significantly better fit compared to the null model (full-null model comparison: $\chi^2 = 4.7973$, df = 2, p = 0.091). However, the model indicated no significant effect of interaction between the location and the day on feeding frequency. Consequently, the interaction was removed from the model, resulting in a significantly better fit for the full model compared to the null model (full-null model comparison: $\chi^2 = 4.7879$, df = 1, p = 0.029) (Table S 9).

The model indicated a significant negative effect of the location variable, indicating that the feeding frequency increased when the apparatus was moved to the new location. Additionally, it showed a highly significant negative effect of the sex variable (estimate = -4.31438, SE = 0.86238, p < 0.001), suggesting that males fed less frequently compared to their female counterparts. Furthermore, the variable NormDS had a significant positive effect on the frequency of feeding (estimate = 0.92108, SE = 0.31942, p = 0.004), implying that subjects higher in the dominance hierarchy fed more frequently (Table S 10).

Effect of leaves on the frequency of feeding:

The full model investigating the effect of the presence or absence of leaves during the Learning Stage 2 and 3 on the frequency of feeding did not demonstrate a significant better fit compared to the null-model (full-null model comparison: $\chi^2 = 4.1737$, df = 2, p = 0.124). However, the model indicated no significant effect of interaction between the presence and the day on feeding frequency. Consequently, the interaction was removed from the model, resulting in a significantly better fit for the full model compared to the null model (full-null model comparison: $\chi^2 = 4.1267$, df = 1, p = 0.042) (Table S 11).

The model revealed a significantly negative effect of leaves being absent (estimate = -0.9038, SE = 0.421, p = 0.032), indicating that the feeding frequency decreased when the leaves were removed. There was no effect of day, sex or dominance rank on the number of times goats fed from the bowl (Table S 12).

Effect of leaves on the frequency of stepping onto the platform

When investigating the effect of the presence or absence of leaves in the Learning Stages 2 and 3, the full-null model comparison found a better fit for the full model (full-null model comparison: $\chi^2 = 7.9652$, df = 2, p = 0.019). The model indicated no significant effect of interaction between the presence or absence of leaves and the day on the frequency of feeding. Therefore, the interaction was removed from the model, which also resulted in a significant better fit for the full model ($\chi^2 = 7.9575$, df = 1, p = 0.005) (Table S 13).

The model showed a significant negative effect of the absence of leaves on the frequency stepping onto the platform (estimate = -2.0008, SE = 0.7976, p = 0.012), implying that goats decreased their platform behaviour when the leaves where removed. There was no significant effect of day, sex or dominance rank on the frequency of stepping onto the platform (Table S 14).

3.1.2 Proximity to feeding bowl and platform

<u>Effect of Learning Stage on the proportion of time in proximity to the feeding bowl:</u>

The full model investigating the effect of stage on the proportion of time goats spent in proximity of the bowl differed significantly from the null model (full-null model comparison: $\chi^2 = 41.275$, df = 7, $p < 0.001$). The model did not demonstrate a significant effect of the interaction between the stages and day. Consequently, the interactions were removed from the model. The new model also showed a significantly better fit when compared to the null model ($\chi^2 = 40.195$, df = 5, $p < 0.001$) (Table S 15).

The model showed significant positive effect of Learning Stage 2 (estimate = 0984, SE = 0.195, $p < 0.001$), and also a significant positive effect of Learning Stage 3 (estimate = 1.1655, SE = 0.31091, $p < 0.001$) on the proportion of time goats spent in proximity of the feeding bowl. Additionally, we found a significant positive effect of the variable day on the proportion of time spent in proximity of the bowl (estimate = 0.20748, SE = 0.06579, p = 0.002). Sex had a significant negative effect on the proportion of time spent in proximity of the bowl (estimate = -1.23398, SE = 0.24322, $p < 0.001$), which implies that males spent significantly less time near the bowl compared to females. Furthermore, the model demonstrated a significant positive effect for the variable NormDS (estimate = 0.51128, SE = 0.11073, $p < 0.001$) showing that subjects with a higher dominance rank spending more time in proximity of the bowl (Table S 16).

Effect of Learning Stage on the proportion of time in proximity to the platform:

The full model investigating the effect of stage on the proportion of time goats spent in proximity to the platform differed significantly from the null model (full-null model comparison: $\chi^2 = 42.23786$, df = 7, $p < 0.001$) (Table S 17).

To model showed a significant positive effect for the interaction between Learning Stage 2 and Day (estimate = 0.30815, SE = 0.13999, p = 0.028), implying that goats spent increasingly more time each day in proximity to platform as the Learning Stage 2 progressed. There was however no such effect for the interaction between Learning Stage 3 and day (estimate = 1.05282, SE = 3.84884, p = 0.784). Additionally, the model showed a significant positive effect of Learning Stage 2 on the proportion of time spent in proximity to the platform (estimate = 1.08307, SE = 0.14225, $p < 0.001$). Sex showed a significant negative effect on the proportion of time in proximity to the platform (estimate = -0.67691, SE = 0.16446, $p < 0.001$), indicating that males spent less time near the platform than females (Table S 18).

Effect of the treat on the proportion of time in proximity to the feeding bowl:

When investigating the effect of treat on the proportion of time goats spent in proximity to the bowl, the full-null model comparison did not find a better fit for the full model (full-null model comparison: $\chi^2 = 3.4116$, df = 2, p = 0.182). This indicates that there was no significant difference of spending time in proximity to the platform between the two treat types that were presented.

Effect of location on the proportion of time in proximity to the feeding bowl:

When investigating the effect of location on the proportion of time goats spent in proximity to the bowl, the full-null model comparison showed a significantly better fit for the full model (full-null model comparison: $\chi^2 = 10.329$, df = 2, p = 0.006). The model indicated no significant effect of interaction between location and day on the time spent in proximity to the bowl, Consequently, the interaction was removed. The new model also showed a significantly better fit when compared to the null model ($\chi^2 = 10.181$, df= 1, $p < 0.001$)

The model demonstrated a significantly negative effect for the variable location on the proportion of time spent in proximity of the bowl (estimate = -0.61017, SE = 0.15363, $p < 0.001$), indicating that goats spent more time in proximity to the bowl after the location of the apparatus was changed.

Effect of leaves on the proportion of time in proximity to the feeding bowl:

The model investigating the effect of the presence or absence of leaves on the proportion of time goats spent in proximity of the bowl did not differ significantly from the null model (full-null model comparison: $\chi^2 = 0.593$, df = 2, p = 0.743).

Effect of leaves on the proportion of time in proximity to the platform:

The model investigating the effect of the presence or absence of leaves on the proportion of time goats spent in proximity of the bowl did not differ significantly from the null model (full-null model comparison: $\chi^2 = 5.1325$, df = 2, p = 0.077).

3.2 Probability of providing food to others compared to one-self during the Learning Stages

The model investigating the effect of day and dominance rank on the probability of goats providing treats prosocially to others, showed a significantly better fit for the full model compared to the null model (full-null model comparison: $\chi^2 = 7.4997$, df = 2, p = 0.024).

The model indicates that day had a significantly negative effect on the receiver (estimate = -0.15495, SE = 0.0621, p = 0.013), indicating that the probability of others receiving a food treat decreases with days.

3.3 Engagement with platform during Testing Stage

When testing the model investigating the effect of Testing Stage on the frequency goats stepped onto the platform, the full-null model comparison showed a significant better fit for the full model (full-null model comparison: $\chi^2 = 33.744$, df = 5, p < 0.001).

The model showed a significantly negative effect for the interaction between Testing Stage 2 and day (estimate = -0.6873, SE = 0.3269, p < 0.036) and also a significantly negative effect for the interaction between Testing Stage 3 and day (estimate = -1.429, SE = 0.3806, p < 0.001), indicating that the stepping behaviour on the platform decreased each day as the respective stage progressed. Testing Stage 2 as well as Testing Stage 3 had a significantly negative effect on the frequency goats stepped onto the platform (estimate = -1.5429, SE = 0.4874, p = 0.002 and estimate = -1.3616, SE = 0.6769, p = 0.044, respectively).

The model using Testing Stage 2 as default stage, did not show a significant effect for Testing Stage 3 (estimate = -10.5432, SE = 0.4999, p = 0.277), suggesting that the frequency goats stepped onto the platform in Testing Stage 3 did not significantly differ from the frequency goats stepped onto the platform in Testing Stage 2.

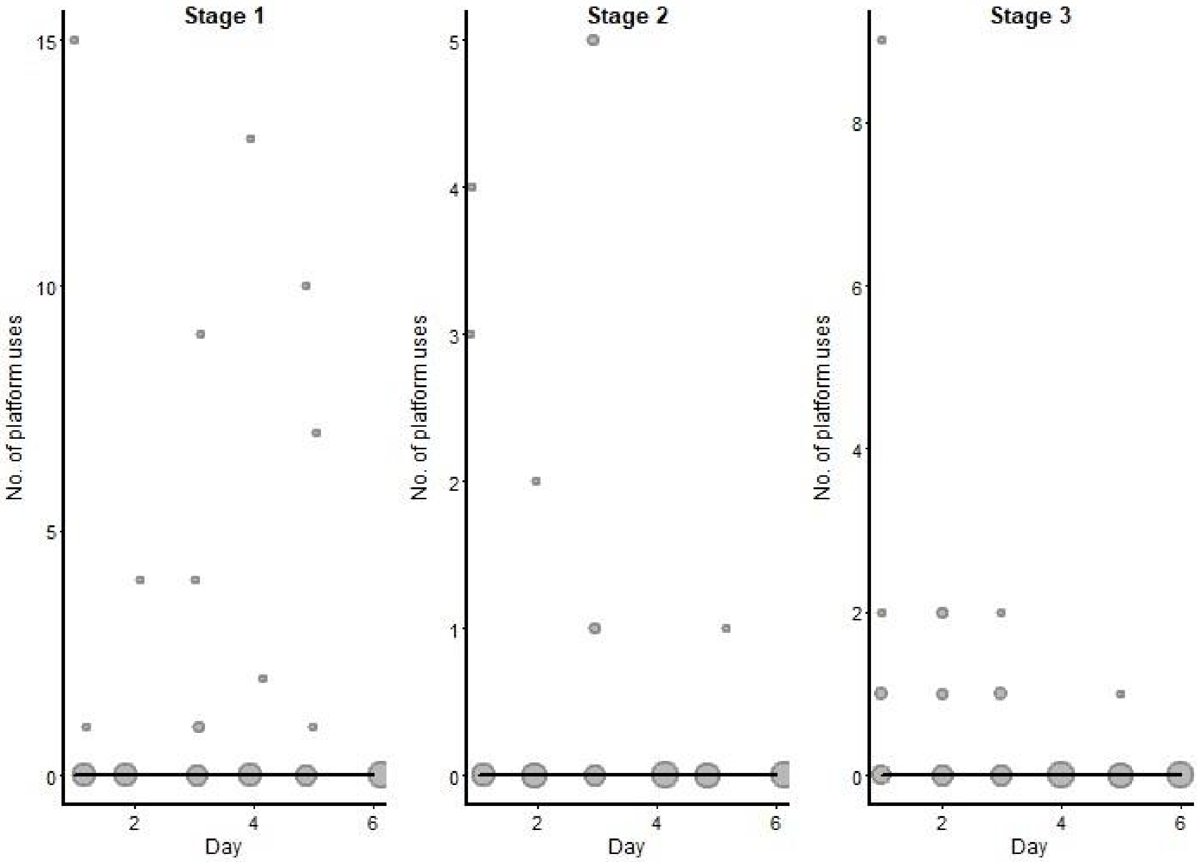

Fig. 13 Number of platform uses per day across the three testing stages. Each plot shows the observed platform events long the solid line representing the fitted model and the shaded line representing its 95% confidence intervals. Confidence band is very narrow. Size of the data point is proportional to the number of observations with that value. Note that the y-axis scale varies between the plots.

3.4 Descriptive Data: Probability of receiving food from individual K1 or K4

Due to limited of data availability, a comprehensive analysis of the donor receiver dyads was not feasible, given that only the individuals K1 and K4 regularly stepped onto the platform. Therefore, the probability of each individual receiving food from these respective individuals during the Learning Phase was calculated. The results indicated that individual K1 got the food in 82.8% of the times for themselves and K4 received food in 3.5% of the time from individual

K1. K4 received in 48.3 % of instances the treats for themselves and K1 received 27.7% of K4's treats (Table S25 and S26).

4. Discussion

Contrary to our expectation that goats would show prosocial tendencies by using the see-saw apparatus to provide treats to conspecifics, the goats did not exhibit prosocial behaviour in this manner. Specifically, goats did not show a higher frequency of stepping onto the platform during Testing Stage 1 and 3 when conspecifics could receive treats compared to Testing Stage 2, in which no one could access the treats. It is noteworthy, the Learning Phase prior to the Testing Phase was not as successful as anticipated. Only a small number of goats stepped onto the platform and from these, there was only evidence that two individuals demonstrated an understanding of how the apparatus worked, by repeatedly stepping onto the platform and running towards the bowl to feed. Even though there was a significant decrease in the frequency with which goats stepped onto the platform between Testing Stage 1 and Testing Stage 2, the frequency of goats stepping onto the platform did not increase again after Testing Stage 2 with no significant difference between Testing Stages 2 and 3. Furthermore, the interaction between stage and testing day revealed a significant difference in the slopes for both Testing Stage 2 and 3, particularly with the significance being more pronounced for Testing Stage 3. Additionally, it was indicated that platform usage decreased in reference to Testing Stage 1 at a faster rate with the passage of days within Testing Stage 3 compared to Testing Stage 2. These results could suggest, that the goats' behaviour of stepping onto the platform was learned though operant conditioning with the treat that they could receive during the Learning Stages for themselves, acting as a positive reinforcer. This association was then extinguished when the behaviour of stepping onto the platform ceased to result in the provision of treats for themselves during the Testing Phase.

It is important to interpret these results with caution due to the limited number of subjects participating during the Testing Phase, which restricts the generalisability of the goats' prosocial behaviour. Engagement with the see-saw apparatus was already limited during the different learning stages, with only few animals feeding from the bowl during the first Learning Stage and even fewer animals using the platform. In order to explore possible reasons behind this overall lack of engagement, the goats' interactions during the Learning Phase were closely examined. These will be discussed in the following paragraphs, offering insights into possible contributing factors to the observed behaviour.

In Learning Stage 1, only a few animals fed from the bowl. An interesting factor to consider is that high-ranking individuals consistently exhibited significantly higher feeding frequency and spent a greater proportion of time in proximity to the bowl throughout all learning stages. This pattern was especially notable during the first Learning Stage, in which higher ranking individuals, especially G4, were observed monopolizing the area of the apparatus, presumably in anticipation of food dropping into the bowl. Lower-ranking individuals frequently faced displacement by the dominant animal when they ventured too close. Although we tried to counteract this behaviour by refraining from the dropping of food until the dominant animal stepped away, it did not increase the feeding frequency of other individuals. Interestingly, dominant goats would exhibit less aggression towards their own offspring, with which they had strong social bonds, as indicated by a high association index (Table S 1-3). Moreover, they seemed to tolerate them feeding from the bowl when given the opportunity. This corroborates the study of Stanley and Dunbar (2013), who found that goats express lower levels of aggression towards closely bonded individuals.

The attempt to increase feeding frequency by alternating pasta pieces and the additional treat type of food pellets on a daily basis, in order to determine whether goats had a preference for one of the two types of treats, did not show a difference between the treat types or an overall increase in feeding frequency. Only when the see-saw apparatus was relocated to a more prominent location in the middle of the outdoor enclosure, a noteworthy change occurred. We observed a significant increase in the frequency of feeding, as well as the time spent in proximity to the bowl. Despite our intention to create a distraction-free environment for the animals by initially placing the see-saw apparatus on the far opposite side of the enclosure, away from the petting zoo, the contrary effect was observed. Even at a considerable distance, the goats were able to see and hear approaching visitors. As soon as visitors came into sight or earshot, the goats ran towards the petting zoo, using vocalizations to signal their conspecifics to follow. This behaviour indicated that the presence of visitors drew the goats' attention away from the apparatus and towards the visitors instead. This was likely because the visitors could provide free food to the goats.

The introduction of suspending leaves above the platform during the second Learning Stage had a profound effect on the goats' interaction with the apparatus. e noticed a substantial increase in both feeding frequency and the frequency of goats stepping onto the platform. Moreover, goats generally spent more time in the vicinity of the feeding bowl and the platform after this stage. The presence of leaves was intended to incentivize the goats to step onto the platform to develop an understanding of the apparatus's mechanism. However, when the leaves were removed in Learning Stage 3, we saw a significant decrease in the frequency of platform uses and only K1 and K4 continued using the apparatus regularly. Both individuals repeatedly stepped on the platform, ran towards the bowl to retrieve the treat, and back to the platform, repeating this process over and over again, suggesting that they understood how the apparatus worked.

Although Learning Stage 2 and Learning Stage 3 were cut short due to time constraints, ending Learning Stage 2 after 15 days and Learning Stage 3 after only 2 days, we did not expect significant changes of behaviour if we had continued. This assumption was drawn from the observation that some goats quickly learned to use the apparatus regularly within the initial five days of Learning Stage 2, while no further improvement was seen in the behaviour of the other goats during the subsequent 10 days. It became apparent that many individuals only displayed interest in the apparatus when leaves were suspended above the platform, or anticipated the receipt of food from the bowl.

From the limited instances when subjects stepped onto the platform and activated the apparatus during the learning stages, several observations were made. Firstly, the donors were more likely to provide treats to themselves rather than others. Secondly, as the Learning Phase progressed, there was an increase in the probability of the donor and receiver being the same individual. This result is similar result to that in the Testing Phase and indicates that goats preferred to provide food for themselves. Specifically, during the Learning Stages K1 provided in 82.6 % of the times it activated the apparatus treats to itself and K4 did so 43.3 % of the time it stepped onto the platform. Both individuals had the highest probability of receiving treats from the respective animal compared to other members of the group. However, there was a possible difference in reciprocation. When K4 activated the apparatus, K1 received the treat in 27.7 % of instances, while K4 only received the treat provided by K1 in 3.4 % of the time.

Although the majority of goats in this study did not use the see-saw apparatus to provide food to their conspecifics or even themselves, K1 and K4 excessively showcased the potential understanding and utilization of this concept by stepping onto the platform up to 190 times within one session of Learning Stage 3. These results align with the outcome of the previous study (Adenot, *unpublished*) that piloted the see-saw apparatus in 2021 with dairy-goats on a farm. In that study, the animals had limited access to pasture and had only 2 to 3 hours per day for grazing, which may have led to constraints, as they may have prioritized grazing over other activities. To address these constraints, we chose a goat population that had constant access to pasture and we chose a different breed. However, despite efforts to avoid previous constraints, we encountered several limitations ourselves, possibly affecting the behaviour of the goats and study outcome. It is important to consider these limitations when interpreting the results of the current study and the outcome, given that they might had a significant influence on the behaviour of the observed group of animals.

The presence of visitors at the petting zoo proved to be a significant distraction and resulted in goats receiving excessive amounts of food pellets without the need for actively engaging with the apparatus. The large number of visitors during the months of June and July led to an abundance of food, causing goats to reduce their activity and refuse to accept more food from visitors most likely due to satiation. Although we scheduled the experimental procedure in the morning and evening to reduce visitor distractions as much as possible, these times did not align with the goat’s most active periods. This resulted in goats spending a notable portion of the experimental time resting.

Of particular note are the suboptimal weather conditions that persisted during the study period and posed additional challenges. During the first Learning Stage and first half of the study period, cold temperatures and frequent rainfall were experienced. These conditions are not favourable for the goats’ despite of their exceptional capability to adapt to nearly all terrains and climates, goats prefer a warmer temperate climate and seek shelter during cold and rainy weather (Bøe and Ehrlenbruch, 2013; Stachowicz et al., 2019). A trait that was observed in our study as well. Temperatures turned from cold at the beginning of the study to very hot in June and July. Although, goats usually thrive in a warmer climate, limited availability of shade within the enclosure led to an apparent avoidance of unnecessary activity by the goats during the hottest days. Additionally, frequent storms occurred and occasionally interrupted the experiment. These factors are likely to have had an influence on the goats' willingness to engage with the apparatus.

Based on our observations, future studies might consider potential modifications to the Learning Phase if a similar experimental procedure with the see-saw apparatus is undertaken. While it is important for goats to establish a mental connection between the sound of a treat dropping into the bowl and the opportunity to feed from it, goats seemed to fixate on the bowl and might have developed an expectation of treats automatically dropping into the bowl. Although the introduction of leaves suspended above the platform during Learning Stage 2 successfully encouraged goats to step onto the platform, goats appeared to become overly focused on reaching and feeding on the leaves. Their focus on the leaves could have prevented them from noticing the treat dropping into the bowl. As a result, the goats might not have learned to associate the behaviour of stepping onto the platform with the treat. The apparatus could have therefore been associated with either receiving food through the leaves or the treat in the bowl but not through actively stepping on the platform.

There are two possible modifications that could be implemented to address these issues. First, a change in the experimental set up to move the bowl next to the platform could be considered. In this case the bowl would be within reach for the individual while standing on the platform. This would be a similar approach to the training phase of the study of Burkart and van Schaik (2013) in which macaques could pull a board closer with one hand while reaching food with the other. Additionally, leaves could be hanging completely out of reach to initiate behaviour of stepping on the platform. In this case goats might notice the treat when it drops into the bowl as they cannot feed from the leaves but could easily reach the treats for themselves. Second, training sessions with smaller groups of two to three animals or even solo training with each subject on their own could be carried out. This would allow goats to focus on the apparatus without the distraction of other individuals. As soon as the goats learn how the apparatus works the group testing could begin. As Briefer et al. (2014) found that even though goats could learn to solve complex puzzle boxes, but failed to obtain this information by social learning, single training sessions might be the best option to guarantee that goats would learn that stepping onto the platform results in the dropping of food into the bowl.

We want to emphasize the importance of incorporating an additional testing stage following the control stage. Several previous studies that employed the group service paradigm conducted only one testing stage with a control stage, leading to claims of prosocial behaviour in specific species, as the apparent prosocial behaviour decreased during the control stage (Burkart and van Schaik, 2013; Burkart et al., 2014). This procedure was criticized by Marshall-Pescini et al. (2016), who pointed out that the decrease might have been a result of reduced motivation rather than a sign of prosocial behaviour during the previous stage. Our current study demonstrates the potential risk of misinterpretation in such cases. During Testing Stage 2, there was a significant decrease of platform uses, which could have led to the conclusion that goats behave prosocially, had it not been for the existence of a third testing stage, where the expected increase in platform uses was not observed. Several other studies have already addressed this concern prior to our study, by incorporating additional testing stages following a control stage, which resulted in more reliable and valid results (Horn et al., 2020; van Leeuwen et al., 2021).

To conclude, even though our study did not provide evidence of proactive prosociality in goats, it is important to understand that this does not completely negate the possibility of goats engaging in proactive prosocial behaviours. The current study faced many limitations like outside distractions from park visitors, unfortunate weather conditions or possible issues with the study design. To further our knowledge and understanding of prosocial behaviour in goats, future studies should take these constraints into account and address them accordingly. This includes minimizing external distractions, scheduling experiments during animals' most active periods and carefully choosing a fitting study design.

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Appendix

<u>Association Index:</u>

To determine the degree of association between the goats, we computed several association indexes, based on the information obtained from the proximity scan samples. We calculated three different association indexes: (1) the association index for goats within one body length of each other, (2) association index for the nearest neighbouring individual, and (3) the association index for goats having direct body contact. These indexes were derived by using the following formula:

Association index = $\frac{Nab}{Na+Nb}$

“ a b” represents the number of times Subject and B were observed close to each other, “ a ” represents the number of times Subject was observed and “ b ” represents the number of times Subject B was observed.

The association index indicates the strength of association between pairs of individuals, with higher values suggesting a greater degree of social affinity between animals.

The results of the association index of goats within one body length of each other are represented in the matrix of Table S 1 and provides insights into the social associations and interactions among all individuals within the group. The values range from 0.1930 to 0 and indicate the strength of associations between the individuals. The pair of subject K1 and K4 exhibiting the highest association index (0.1930) with the pairs of subject K2 and K3 (0.1900) and K5 and K6 (0.1897) second and third respectively.

These connections can also be seen in the matrix of association index nearest neighbour (Table S 2) and in the matrix of association index of goats with direct body contact (Table S 3).

Table S 1 The association index matrix of goats within one body length of each other. High values indicating strong social associations are highlighted.

	G1	G2	G3	G4	G5	G6	G7	G8	K1	K2	K3	K4	K5	K6
G1														
G2	0.0062													
G3	0.0041	0.0344												
G4	0	0.0133	0.0217											
G5	0.0021	0.1253	0.0404	0.0578										
G6	0	0.0056	0.0112	0	0.0112									
G7	0.0177	0.0582	0.0433	0.0213	0.0369	0								
G8	0	0.0123	0.0045	0.0067	0.0135	0.1138	0							
K1	0.0642	0.0235	0.0139	0.0036	0.0428	0.0022	0.0495	0.0022						
K2	0.0114	0.0145	0.0211	0.1103	0.0380	0.0034	0.0276	0.0034	0.0283					
K3	0.0062	0.0096	0.0368	0.1284	0.0470	0.0022	0.0276	0.0022	0.0319	0.1900				
K4	0.0519	0.0422	0.0278	0.0054	0.0476	0.0022	0.0652	0	0.1930	0.0272	0.0302			
K5	0.0114	0.0241	0.1511	0.0193	0.0428	0.0045	0.0395	0.0022	0.0441	0.0568	0.0501	0.0369		
K6	0.0062	0.0300	0.1140	0.0138	0.0467	0.01	0.0255	0.0100	0.0593	0.0486	0.0534	0.0480	0.1897	

Table S 2 The association index matrix of nearest neighbour. High values indicating strong social associations are highlighted.

	G1	G2	G3	G4	G5	G6	G7	G8	K1	K2	K3	K4	K5	K6
G1														
G2	0.0021													
G3	0.0041	0.0229												
G4	0	0.0066	0.0127											
G5	0.0010	0.1771	0.0277	0.0446										
G6	0	0.0022	0.0090	0.0034	0.0022									
G7	0.0133	0.0802	0.0357	0.0138	0.0200	0								
G8	0	0.0090	0.0022	0.0067	0.0067	0.1707	0							
K1	0.0414	0.0108	0.0048	0.0018	0.0283	0.0034	0.0376	0						
K2	0.0010	0.0084	0.0097	0.1007	0.0193	0.0022	0.0169	0	0.0163					
K3	0	0.0042	0.0169	0.1019	0.0350	0.0022	0.0175	0.0034	0.0205	0.2334				
K4	0.0322	0.0223	0.0115	0.0024	0.0374	0.0011	0.0489	0	0.2618	0.0151	0.0103			
K5	0.0042	0.0121	0.1692	0.0091	0.0266	0.0011	0.0207	0.0011	0.0181	0.0326	0.0314	0.0218		
K6	0.0010	0.0198	0.1140	0.0054	0.0407	0.0044	0.0093	0.0022	0.0437	0.0366	0.0366	0.0300	0.2083	

Table S 3 The association index matrix of goats with direct body contact. High values indicating strong social associations are highlighted.

	G1	G2	G3	G4	G5	G6	G7	G8	K1	K2	K3	K4	K5	K6
G1														
G2	0													
G3	0	0												
G4	0	0.0012	0.0012											
G5	0	0.0657	0.0024	0.0036										
G6	0	0	0.0034	0.0045	0									
G7	0.0055	0.0344	0.0088	0.0013	0.0025	0								
G8	0	0	0	0.0022	0	0.0813	0							
K1	0.0166	0.0024	0.0024	0	0.0078	0.0022	0.0106	0						
K2	0	0	0.0036	0.0319	0.0024	0	0.0019	0	0.0006					
K3	0	0	0.0012	0.0241	0.0036	0	0.0013	0.0022	0.0024	0.089				
K4	0.0145	0.0012	0.0024	0	0.0133	0	0.0082	0	0.1001	0.0030	0			
K5	0	0	0.0816	0	0.0006	0	0.0050	0	0.0006	0.0060	0.0036	0.0024		
K6	0.0021	0.0048	0.0570	0	0.0120	0	0	0	0.0060	0.0084	0.0048	0.0048	0.0966	

Social group network diagram:

e employed the “igraph” package (version . . , Csardi and e pusz,) to generate a visual representation of the relationships among the goats within the group. Utilizing the data of nearest neighbours, and adjacency matrix was created to construct the group network diagram. The columns of the matrix represented the focal individual and the rows represented their closest conspecific. We created a graph object by using the adjacency matrix and incorporated both incoming and outgoing connections using the “plus” mode. dditi onally, we assigned weights to the connections based on the values in the matrix. Finally, the network diagram was plotted using the “plot” function from the “igraph” package.

The social group network represents the relationship between subjects based on the nearest neighbouring individuals. Each subject is represented as a node in the diagram. Relationships or connections between individual pairs are indicated by the presence of a line between the two nodes. Proximity of nodes and the number of edges between them suggest the frequency of individuals being closest to each other and the strength of their relationship

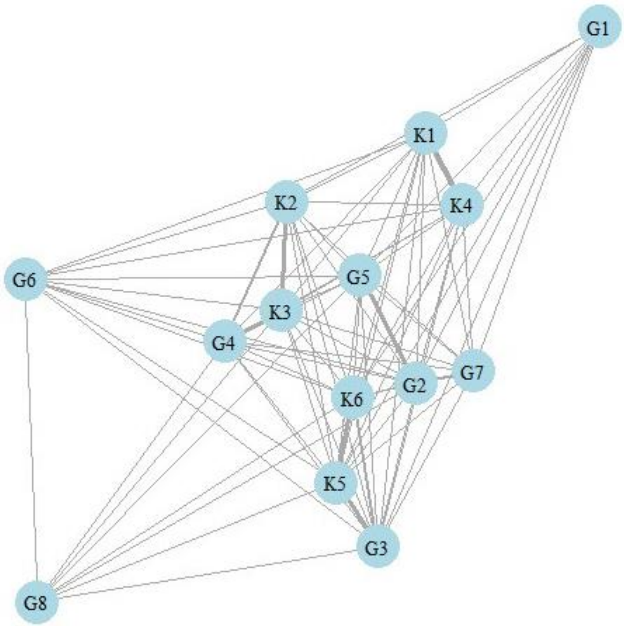

Fig. S 1 Social Group Network of nearest neighbouring individual.

Dominance rank:

Table S 4 Dominance Hierarchy indicating rank, subject and NormDS. Rows with a grey background indicate subjects that left the group during the study.

Rank	Subject	NormDS
1	G7	10.298658
2	G4	10.09639
3	G1	10.081681
4	G8	8.539297
5	G3	7.802814
6	G2	7.351176
7	G5	7.120306
8	G6	7.084137
9	K6	5.572463
10	K4	4.997845
11	K1	4.174752
12	K5	3.341095
13	K3	2.369228
14	K2	2.170158

Tables with model output:

Table S 5 Full model output of full-null model comparison analysing the effect of the Learning Stages on the frequency of feeding.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	6	2352.4	2378.9	-1170.2	2340.4			
full	11	2330.8	2379.4	-1154.4	2308.8	31.583	5	< 0.001

Table S 6 Full model output of GLMM analysing the effect of the Learning Stages on the frequency of feeding from the feeding bowl.

Term	Estimate	SE	z-value	p-value
Intercept	-9.4169	0.2699	-34.889	< 0.001
LearningStage2[1]	2.103	0.6364	3.304	< 0.001
LearningStage3[1]	1.415	0.9224	1.534	0.125014
Day[2]	0.4001	0.2264	1.767	0.077192
Sex.male[3]	-2.3765	0.4202	-5.656	< 0.001
NormDS[2]	0.9599	0.1821	5.271	< 0.001

[1] Dummy coded with Learning Stage 1 being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 7 Full model output of full-null model comparison analysing the effect of the Learning Stages on the frequency of stepping onto the platform.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	3	1222.85	1236.1	-608.43	1216.85			
full	10	985.52	1029.7	-482.76	965.52	251.33	7	< 0.001

Table S 8 Full model output of GLMM analysing the effect of the Learning Stages on the frequency of stepping onto the platform.

Term	Estimate	SE	z-value	p-value
Intercept	-13.6386	0.5534	-24.643	< 0.001
LearningStage2[1]	5.4066	0.3811	14.186	< 0.001
LearningStage3[1]	-0.1563	11.6085	-0.013	0.98926
Day[2]	-0.6894	0.2858	-2.413	0.01584
Sex.male[3]	-2.5417	0.9941	-2.557	0.01056
NormDS[2]	0.5479	0.4194	1.306	0.19145
LearningStage2:Day	1.143	0.4269	2.678	0.00741
LearningStage3:Day	-2.4603	9.1823	-0.268	0.78874

[1] Dummy coded with Learning Stage 1 being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 9 Full model output of full-null model comparison analysing the effect of the location of the apparatus on the frequency of feeding.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	8	522.67	546.97	-253.34	506.67			
full	9	519.88	547.22	-250.94	501.88	4.7879	1	0.02866

Table S 10 Full model output of GLMM analysing the effect of the location of the apparatus on the frequency of feeding from the feeding bowl.

Term	Estimate	SE	z-value	p-value
Intercept	-7.94952	0.36935	-21.523	< 0.001
Locationold[1]	-0.904	0.41872	-2.159	0.03085
Day[2]	0.02578	0.07953	0.324	0.74585
Sex.male[3]	-4.31438	0.86238	-5.003	< 0.001
NormDS[2]	0.92108	0.31942	2.884	0.00393

[1] Dummy coded with Locationnew being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 11 Full model output of full-null model comparison analysing the effect of presence or absence of leaves on the frequency of feeding.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	11	275.1	294.73	-126.55	253.1			
full	12	272.97	294.38	-124.49	248.97	4.1267	1	0.04221

Table S 12 Full model output of GLMM analysing the effect of the presence or absence of leaves on the frequency of feeding from the feeding bowl.

Term	Estimate	SE	z-value	p-value
Intercept	-7.9325	0.6049	-13.114	< 0.001
Leavesabsence[1]	-0.9038	0.421	-2.147	0.0318
Day[2]	-0.1441	0.1881	-0.766	0.4436
Sex.male[3]	0.1582	1.5504	0.102	0.9187
NormDS[2]	-0.5205	0.5476	-0.95	0.3419

[1] Dummy coded with Leavespresence being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 13 Full model output of full-null model comparison analysing the effect of presence or absence of leaves on the frequency of stepping onto the platform.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	6	182.66	193.37	-85.33	170.66			
full	7	176.7	189.19	-81.352	162.7	7.9575	1	0.004789

Table S 14 Full model output of GLMM analysing the effect of the presence or absence of leaves on the frequency of stepping onto the platform.

Term	Estimate	SE	z-value	p-value
Intercept	-9.4728	1.5816	-5.99	< 0.001
Leavesabsence[1]	-2.0008	0.7976	-2.508	0.0121
Day[2]	-0.1694	0.3397	-0.499	0.618
Sex.male[3]	-5.7136	3.3544	-1.703	0.0885
NormDS[2]	2.4153	1.6218	1.489	0.1364

[1] Dummy coded with Leavespresence being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 15 Full model output of full-null model comparison analysing the effect of the Learning Stages on the proportion of time spent in proximity of the feeding bowl.

	df	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	6	-2557.3	-2530.8	1284.6	-2569.3			
full	11	-2587.5	-2538.8	1304.7	-2610.6	40.195	5	< 0.001

Table S 16 Full model output of GLMM analysing the effect of the Learning Stages on the frequency of proportion of time spent in proximity of the feeding bowl.

Term	Estimate	SE	z-value	p-value
Intercept	-2.78591	0.13216	-21.079	< 0.001
LearningStage2[1]	0.984	0.195	5.046	< 0.001
LearningStage3[1]	1.1655	0.31091	3.749	< 0.001
Day[2]	0.20748	0.06579	3.153	0.001613
Sex.male[3]	-1.23398	0.24322	-5.074	< 0.001
NormDS[2]	0.51128	0.11073	4.617	< 0.001

[1] Dummy coded with Learning Stage 1 being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 17 Full model output of full-null model comparison analysing the effect of the Learning Stages on the proportion of time spent in proximity of the platform.

	df	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	7	-3804.888	-3773.948	1909.444	-3818.888			
full	14	-3833.126	-3771.246	1930.563	-3861.126	42.23786	7	< 0.001

Table S 18 Full model output of GLMM analysing the effect of the Learning Stages on the frequency of proportion of time spent in proximity of the platform.

Term	Estimate	SE	z-value	p-value
Intercept	-4.0388	0.0981	-41.17	< 0.001
LearningStage2[1]	1.08307	0.14225	7.61	< 0.001
LearningStage3[1]	1.65214	4.8616	0.34	0.734
Day[2]	-0.0718	0.05169	-1.39	0.1648
Sex.male[3]	-0.67691	0.16446	-4.12	< 0.001
NormDS[2]	0.13255	0.07349	1.8	0.0713
LearningStage2:Day	0.30815	0.13999	2.2	0.0277
LearningStage3:Day	1.05282	3.84884	0.27	0.7844

[1] Dummy coded with Learning Stage 1 being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 19 Full model output of full-null model comparison analysing the effect of location of the apparatus on the proportion of time spent in proximity of the feeding bowl.

	df	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	8	-601.01	-576.72	308.51	-617.01			
full	9	-609.19	-581.86	313.6	-627.19	10.181	1	0.001419

Table S 20 Full model output of GLMM analysing the effect of location on of the apparatus on the proportion of time spent in proximity of the feeding bowl.

Term	Estimate	SE	z-value	p-value
Intercept	-2.07308	0.19596	-10.579	< 0.001
Locationold[1]	-0.61017	0.15363	-3.972	< 0.001
Day[2]	0.08263	0.0607	1.361	0.1734
Sex.male[3]	-1.60235	0.38825	-4.127	< 0.001
NormDS[2]	0.39885	0.16793	2.375	0.0175

[1] Dummy coded with Locationnew being the reference category
[2] z-transformed to mean = 0 and sd = 1
[3] Dummy coded with Sex.female being the reference category

Table S 21 Full model output of full-null model comparison analysing the effect of Testing Stages on the frequency of stepping onto the platform.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	5	289.44	305.88	-139.72	279.44			
full	10	265.7	298.58	-122.85	245.7	33.744	5	< 0.001

Table S 22 Full model output of GLMM analysing the effect of the Testing Stages on the frequency of stepping onto the platform.

Term	Estimate	SE	z-value	p-value
Intercept	-11.3577	0.8744	-12.989	< 0.001
TestingStage2[1]	-1.5429	0.4874	-3.166	0.001547
TestingStage3[1]	-1.3616	0.6769	-2.011	0.044283
Day[2]	-0.3098	0.2255	-1.374	0.169475
TestingStage2:Day	-0.6873	0.3269	-2.102	0.035528
TestingStage3:Day	-1.429	0.3806	-3.754	< 0.001
TestingStage3[3]	-0.5432	0.4999	-1.087	0.277169

[1] Dummy coded with TestingStage1 being the reference category

[2] z-transformed to mean = 0 and sd = 1

[3]details extracted by releveling variable “stage” to Testing Stage

Table S 23 Full model output of full-null model comparison analysing the effect of day and dominance rank on the probability of others receiving food.

	npar	AIC	BIC	logLink	deviance	Chisq	df	p-value
null	2	1783.248	1794.402	-889.6242	1779.248			
full	3	1779.749	1802.055	-885.8743	1771.749	7.499689	2	0.0235214

Table S 24 Full model output of GLMM analysing the effect of day and dominance rank on the probability of others receiving food

Term	Estimate	SE	z-value	p-value
Intercept	-2.56539	0.81617	-3.143	0.00167
Day[2]	-0.15495	0.06261	-2.475	0.01333
NormDS[2]	-0.52241	0.4364	-1.197	0.23128

[2] z-transformed to mean = 0 and sd = 1

Table S 25 Probability goats receiving treats from K1 during the Learning Stages.

Donor	Receiver	Number of food provisioning	Probability
K1	K1	1117	0.8286
K1	K4	47	0.0349
K1	no-one	31	0.0230
K1	G7	27	0.0200
K1	G3	25	0.0185
K1	G2	24	0.0178
K1	K2	21	0.0156
K1	K6	16	0.0119
K1	K5	16	0.0119
K1	G5	14	0.0104
K1	K3	6	0.0045
K1	G4	4	0.0030

Table S 26 Probability goats receiving treats from K4 during the Learning Stages.

Donor	Receiver	Number of food provisioning	Probability
K4	K4	150	0.4839
K4	K1	86	0.2774
K4	G2	18	0.0581
K4	G5	10	0.0323
K4	G4	8	0.0258
K4	G3	8	0.0258
K4	no-one	7	0.0226
K4	G7	6	0.0194
K4	K2	6	0.0194
K4	K3	5	0.0161
K4	K6	5	0.0161
K4	K5	1	0.0032