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Addressing Pigs: A Comparative Study on Pigs' Selective Sensitivity to Human Ostensive Communication

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Abstract

Humans communicate ostensively when they convey their communicative intentions, e.g., by calling the addressee's name and/or by establishing eye-contact. Dogs, cats and horses are more attentive and/or learn more effectively after being addressed. To what extent these species' sensitivity to ostension depends on selection for companionship, and to what extent on individual experience with human communication, remains unclear. Here we investigated the role of exposure to human communication in facilitating the development of such sensitivity in a species domesticated for purposes other than companionship, the domestic pig. To test the hypothesis that, at least after sufficient experience with humans, pigs are sensitive to human ostensive communication, we subjected companion pigs (n=8), lab pigs kept for behavioral research (n=31) and commercially farmed breeding sows (n=15) to ostensive and non-ostensive versions of three tasks. We hypothesized that pigs should be more attentive to ostensive than non-ostensive demonstrations and that, due to or independently of attentiveness, in a detour task and an object-choice task, pigs would follow ostensive human demonstrations or directional cues more than non-ostensive ones, and would err more in the ostensive than in the non-ostensive version of an A-not-B error task. Further, if experience with human communication modulates sensitivity to ostension in pigs, we expected that these effects increase from commercial, through lab, to companion pigs. Pigs were more attentive to ostensive detour demonstrations than non-ostensive ones, but otherwise ostension did not enhance pigs' attentiveness or learning. Further, pig groups differed, with lab pigs generally being most successful and attentive. These findings indicate that, independently of individual experience, human ostensive communication can increase pigs' attentiveness but might enhance their learning less than in species selected for companionship. Instead, our results highlight the influence of training experience and an enriched keeping environment on pigs' performance in cognitive tests.

Zusammenfassung

Menschen kommunizieren ostensiv, wenn sie ihre kommunikativen Absichten mitteilen, etwa indem sie den Namen des Angesprochenen rufen oder Blickkontakt herstellen. Hunde, Katzen und Pferde sind aufmerksamer und lernen effektiver, nachdem sie angesprochen wurden. Es ist unklar, wie stark die Sensibilität gegenüber Ostension dieser Tierarten auf die Selektion für das Heimtierdasein und wie stark auf ihre individuelle Erfahrung mit menschlicher Kommunikation zurückzuführen ist. Wir untersuchten die Rolle der Erfahrung mit menschlicher Kommunikation im Hervorbringen einer solchen Sensibilität in einer Art, die nicht als Heimtier domestiziert wurde, dem Hausschwein. Um unsere Hypothese zu prüfen, dass Schweine, zumindest mit ausreichend Erfahrung mit Menschen, sensibel auf menschliche ostensive Kommunikation reagieren, testeten wir als Heimtiere gehaltene Minischweine (n=8), Laborschweine, die für Verhaltensforschung gehalten werden (n=31), und kommerziell gehaltene Zuchtsauen (n=15) in ostensiven und nicht-ostensiven Versionen von drei Tests. Gemäß unserer Hypothese sollten Schweine während ostensiver Demonstrationen aufmerksamer sein als während nicht-ostensiver und, abhängig oder unabhängig von der Aufmerksamkeit, sollten sie ostensiven menschlichen Demonstrationen und direktionalen Hinweisen in einem Detour-Test und einem Objektwahl-Test besser folgen als nicht-ostensiven und in einer ostensiven Variante eines A-not-B-Tests mehr Fehler begehen als in einer nicht-ostensiven. Falls Erfahrung mit menschlicher Kommunikation diese Sensibilität moduliert, erwarteten wir weiters, dass diese Effekte von den kommerziellen über die Laborschweine bis zu den Minischweinen zunehmen sollten. Die Schweine waren während ostensiver Detour-Demonstrationen aufmerksamer als während nicht-ostensiver, aber abgesehen davon steigerte Ostension weder ihre Aufmerksamkeit noch ihre Lerneffizienz. Weiters unterschieden sich die Schweinegruppen, insofern als die Laborschweine generell am erfolgreichsten und aufmerksamsten waren. Diese Ergebnisse deuten darauf hin, dass menschliche ostensive Kommunikation unabhängig von individueller Erfahrung die Aufmerksamkeit von Schweinen steigern kann, obwohl sie sich weniger auf das Lernen auswirkt als bei als Heimtiere selektierten Arten. Stattdessen unterstreichen unsere Ergebnisse den Einfluss von Trainingserfahrung und artegerechten Haltungsbedingungen auf die Leistung von Schweinen in kognitiven Tests.

Keywords

Ostensive communication, domestic pig, *Sus scrofa domesticus*, object-choice task, A-not-B task, detour task, companion pig, experience with humans, enrichment

Schlagwörter

Ostensive Kommunikation, Hausschwein, *Sus scrofa domesticus*, Objektwahl-Test, A-not-B-Test, Detour-Test, Schwein als Heimtier, Erfahrung mit Menschen, Enrichment

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1. Introduction

1.1 Uniquely Human Ostensive Communication: Production and Reception

One of the unique characteristics of human communication is ostension. Communicating ostensively means transmitting one's communicative intentions, i.e., intentions to make the addressee aware of the sender's intention to inform them (Csibra, 2010; Heintz & Scott-Phillips, 2022; Scott-Phillips, 2015). In other words, ostension indicates the communicative nature of a signal; it "signals signalhood" (Scott-Phillips, 2015, p. 58). For example, senders might call the addressee's name before an informative action is performed, establish eye-contact or exaggerate their informative demonstration using theatrical movements. This can substantially change the addressee's perception of the context (as communicative) and, consequently, their reception of the information provided (as referential and/or generalizable (Csibra, 2010; Csibra & Gergely, 2011; Topál et al., 2008)). In human communication, ostension thus plays a crucial role in facilitating teaching (Bard & Vauclair, 1984; Csibra & Gergely, 2011) and coordination. Most importantly, ostensive communication is quintessential to human language (Heintz & Scott-Phillips, 2022).

However, even individuals who do not (yet) produce ostensive signals can nevertheless be sensitive to them. In humans, the production of ostensive communication develops relatively late. For example, three-year-old human children can hide their communicative intentions when secretly informing an adult experimenter (Grosse et al., 2013), which indicates an understanding of the distinction between informative and communicative intentions. In contrast, infants' sensitivity to adults' ostensive communication seems to develop considerably earlier. Behne et al. (2005) could show that, starting at 14 months of age, children can interpret an adult's ostensive behavior in a hiding game as relevant for them. That is, their success at following the experimenter's pointing and gazing was only significantly above chance level if these directional cues were given in an ostensive manner. Similarly, 13-month-olds were shown to recognize communicative intentions when watching third-party interactions (Tauzin & Gergely, 2018). Even earlier, at the age of six months, human infants' gaze following is enhanced by eye-contact and infant-directed speech, which likely reflects a reflexive responding to ostensive signals (Senju & Csibra, 2008). At this early age, infants are already clearly sensitive to certain components of ostensive signals. For instance, from five months of age, infants recognize their own name in a stream of speech (Mandel et al., 1995; Newman, 2005), one-month-olds prefer infant directed to adult-directed speech (Cooper & Aslin, 1990) and neonates prefer faces with open, rather than closed, eyes (Batki et al., 2000). Taken together, also non-verbal individuals that do not produce ostensive signals themselves can be sensitive to ostensive communication directed at them.

To find out whether changes in subjects' reaction are selective to ostensive – but not non-ostensive – contexts, a direct comparison of the two signal types can be performed. For example, ostensive signaling can consist in the experimenter calling the subject's name and/or establishing eye-contact before information (e.g., directional cues such as pointing or gazing at a baited location) is presented (Behne et al., 2005; Byosiere et al., 2022; Kaminski et al., 2012). In contrast, similar directional cues (hand gesture or gaze) can also be conveyed without being accompanied by ostension. For instance, one can extend one's arm to check a watch (as used in Kaminski et al., 2012) or to massage one's shoulder (as used in Byosiere et al., 2022). In the latter case, the experimenter does not convey any communicative intention, even though the subject can utilize the directional cues provided to locate the hidden reward.

Young human infants' differential reactions to ostensive as opposed to non-ostensive signals (Behne et al., 2005; Topál et al., 2008) pose the question whether humans' sensitivity is shared by (some) non-human animals. In this context, being sensitive means that addressees "reliably alter their behaviour in the presence of such stimuli to obtain reinforcement that depends on the instruction or mediation of a human companion" (Udell et al., 2009, p. 329). In human infants, this sensitivity to ostension can manifest in terms of increased attentiveness towards the source of the signal (e.g., the experimenter) or, independently of differences in attentiveness (e.g., Yoon et al., 2008), it can change the way the ostensively presented content is learned and interpreted (Csibra & Gergely, 2011). For instance, human infants focus more on the identity of the stimuli, rather than their location, in ostensive contexts (Yoon et al., 2008). In a similar vein, they generalize the previously learned location of an object to subsequent trials despite having seen the same or a different experimenter ostensively hide the object elsewhere (Topál et al., 2008).

1.2 Ostension in Human-Animal Communication

Human communication with all its unique characteristics is not limited to intraspecific exchange of information. On the contrary, also non-human animals are frequently the addressees of uniquely human forms of communication. For example, in analogy with infant-directed speech, which is characterized by slower pace and higher pitch than adult-directed speech (Fernald, 1992), humans frequently engage in pet-directed speech with animals (Ben-Aderet et al., 2017). Indeed, similar to infants, pet-directed speech has been shown to increase dogs' reactivity (Ben-Aderet et al., 2017) and attentiveness (Jeannin et al., 2017), and similar effects have been reported for horses (Jardat et al., 2022). As humans routinely make use of these and other ostensive signals when addressing animals, the latter might also be sensitive to ostension.

To pinpoint the evolutionary and ontogenetic origins of sensitivity to ostension, several non-human animal species have been tested to investigate whether they respond to human ostension by either increased attentiveness or by attentiveness-independent enhanced learning. Not surprisingly, the search for selective sensitivity to ostensive communication in non-human animals has initially focused on humans' closest relatives, namely great apes. For example, interesting differences between humans and apes have been revealed by observing parent-offspring interactions in object manipulation contexts. In a study by Bard and Vauclair (1984), the human mothers or caretakers were more engaged in attracting the infant's (human, chimpanzee or bonobo) attention to the objects (e.g., by pointing to them) than the adult chimpanzee and the adult bonobo. Also, the human-human dyad showed the most pronounced patterns of joint attention and behavioral synchrony following these instances of attention-getting, while the mother and the infant in the chimpanzee-chimpanzee and bonobo-bonobo pairs manipulated the objects rather independently. However, when paired with a human caretaker, the chimpanzee (but not the bonobo infant) showed more human-like reaction patterns. Despite this, apes generally perform relatively poorly in utilizing diverse human cues: Unlike human infants, apes struggle to follow human directional gestures in object-choice tasks, even if ostensive signals (such as establishing eye-contact) accompany these gestures (Herrmann & Tomasello, 2006; Povinelli et al., 1997).

Aside from primates, another group of animals phylogenetically more distant from humans but nevertheless well-adapted to the anthropogenic niche is worth investigating: companion animal species. As described above, companion animals are frequently the addressees of human ostensive communication and might therefore have evolved specific sensitivity to ostension.

A variety of paradigms have been employed to probe selective sensitivity to ostension in companion animals via a comparison of ostensive and non-ostensive contexts. Three of these are a) object-choice tasks (where animals can locate hidden food based on directional human-given cues), b) A-not-B tasks (where animals may commit the so-called "A-not-B error" when, after having found a reward repeatedly in the same location that was indicated by conspicuous hiding, the reward is now conspicuously hidden in a new location) and c) detour tasks (where animals can learn to make a detour by observing a human demonstrator).

First, ostensive signaling has been shown to influence animals' performance in object-choice tasks. While many animal species can follow human pointing and/or gazing (e.g., dogs (Kirchhofer et al., 2012), goats (Kaminski et al., 2005; Nawroth et al., 2020), horses (Lansade et al., 2021), cats (Pongrácz et al., 2019) and, at least in one study, pigs (Nawroth et al., 2014)), only a few *selectively* respond to ostensive signaling. For example, similar to human infants (Behne et al., 2005), horses are more successful in locating hidden food indicated by an experimenter if a pointing gesture is accompanied by pet-directed, rather than adult-directed, speech (Lansade et al., 2021). In ostensive contexts, also dogs are more successful in choosing indicated objects (Kaminski et al., 2012) and in following human gaze into distant space (Duranton et al., 2017). In contrast, cats' performance in an object-choice task was not enhanced by ostension, but they were quicker to look at the experimenter's pointing (i.e., paid more attention) after ostensive signals (e.g., "Look!" or cat-calling noises) than after non-ostensive clicking noises (Pongrácz et al., 2019). This pattern of results for cats also raises the question whether dogs' and horses' enhanced performance in ostensive contexts might merely be mediated by increased attentiveness. Following the methodology of a comparable study on human infants (Senju & Csibra, 2008), Téglás et al. (2012) therefore used eye-tracking to ascertain that dogs' enhanced gaze-following in ostensive contexts cannot solely be attributed to differences in attentiveness. For this aim, the researchers also used a non-ostensive stimulus to attract the dogs' attention before the gaze cue was delivered and eye-tracking allowed them to measure and compare the dogs' attentiveness between conditions. Indeed, dogs looked equally long at the experimenter during the addressing phase of the two conditions. Nevertheless, an even more convincing argument that animals' enhanced learning in ostensive contexts is attentiveness-independent comes from paradigms in which increased attentiveness would in fact counter-act the expected effects of ostension.

This is the case in another task also suitable to probe selective sensitivity to ostensive signals: in the so-called A-not-B-task. In A-not-B tasks, one of two locations ("A") is baited conspicuously over several trials, before the target's location is switched to the other side ("B"). Even though they should "know better" after having observed the baiting process, both human infants (Topál et al., 2008) and dogs (Kis et al., 2012) continue to search in the initial, now incorrect location ("A"), committing the so-called "A-not-B" error. Importantly, both species perseverate significantly more after ostensive hiding (e.g., when the experimenter calls their name before hiding the target) than after non-ostensive hiding. This is in contrast with the interpretation that ostension simply increases subjects' attentiveness. If this were the case, they should better follow the hiding at the new location and make fewer mistakes in the ostensive than non-ostensive trials. This is exactly what cats did in this task: they showed the A-not-B error when the experimenter or the owner non-ostensively hid the target, but not in the ostensive-experimenter condition (Pongrácz & Onofer, 2020). These results led the authors to conclude that, like in the object-choice task (Pongrácz et al., 2019), ostension might mainly affect cats' attentiveness rather than their learning. In contrast, there seem to be other mechanisms at play in dogs and infants, who both commit the error more after ostensive hiding. However, there exists a crucial difference between the behavior of the two species. While infants continued to commit the error even if the experimenter changed after the A trials (i.e., a second experimenter took over for the B trials), dogs correctly chose screen B after the switch. This indicates that, potentially, infants interpret the information presented in ostensive A trials as generalizable (across trials and experimenters), while dogs perseverate on location A in the B trials because they perceive the ostensive hiding during the A trials as an imperative to keep searching there (Topál et al., 2008).

The effect of ostension on learning becomes even more salient when subjects are encouraged to learn from the demonstrator's actions and their outcomes. For instance, a demonstrator can show the subject how to detour a barrier (e.g., a V-shaped fence) to reach a target (e.g., a toy or food). These so-called detour tasks have been extensively used to research animals' reactions to ostensive and non-ostensive demonstrations, yielding remarkable results. An early study by Pongrácz et al. (2001) showed that domestic dogs, unlike dingoes (Smith & Litchfield, 2010), struggle to solve the task on their own. That is, their latency to succeed did not decrease over six trials. In contrast, even initially unsuccessful dogs improved after watching a human demonstration. Follow-up studies could clarify that neither a scent trial nor demonstrations by the owner or the experimenter carrying the target but without talking to the dog were effective. Instead, verbal attention-getting was what made the detour demonstration most effective (Pongrácz et al., 2004). No differences in visual orientation (distractedly looking away from the demonstrator) were detected between ostensive and non-ostensive conditions. Additionally, the effect was independent of the dog's familiarity with the experimenter (Pongrácz et al., 2004) as well as its age (Pongrácz et al., 2005), while results about potential differences between cooperative and independent breeds are conflicting (Dobos & Pongrácz, 2023; Pongrácz et al., 2005).

Unlike dogs, horses' latency to solve the detour task did not significantly decrease after watching a human demonstrator (Burla et al., 2018), even if the human talked to the subject (Henriksson et al., 2019). However, Henriksson et al. closed the side horses were initially successful on (on their own). This might have confounded the results since the dogs in Pongrácz et al. (2001) improved after the demonstration *without* necessarily choosing the demonstrator's side (instead, they often opted for the side of their first successful trial). In contrast, goats are very adept at learning from a human demonstrator in a detour task, even in the absence of ostensive signals (Nawroth et al., 2016). Hence, while dogs clearly show enhanced learning in reaction to ostensive demonstrations in detour tasks, horses' and goats' performance does not yet provide evidence for their selective sensitivity to ostensive signals.

Taken together, directly comparing subjects' reaction to ostensive and non-ostensive versions of various tasks has yielded three different patterns of (selective) reaction to ostension: no sensitivity (i.e., the same reaction to ostensive and non-ostensive signals), increased attentiveness (i.e., looking at the experimenter and/or the task) or enhanced learning (by being more likely to interpret the information as generalizable or referential, as in human infants (Csibra, 2010; Topál et al., 2008)).

1.3 Evolutionary and Developmental Origins of Sensitivity to Human Ostensive Communication

Ostensive communication seems to create a unique learning context in which companion animals may become more receptive to information provided by a human demonstrator. However, it remains unclear exactly which evolutionary processes during domestication and artificial selection have led dogs, horses and cats to develop sensitivity to ostension. While dogs, for example, are not only domesticated but were also selected for companionship and cooperation with humans (Hare et al., 2002; Miklósi & Soproni, 2006), other domesticated animals have been selected for production traits instead (e.g., goats (Kaminski et al., 2005)). In addition, individual dogs living in human households gain considerably more experience with humans and their communication than the average farm animal individual. Consequently, reviewing the accumulating evidence for companion animals' selective reaction to ostension in various paradigms, the question arises to what extent their sensitivity to human ostension originates from (1) domestication, (2) selection for companionship, and to what extent from (3) their exposure to humans and their unique communication. In other words, it is currently unclear whether all domesticated animals (with sufficient experience) are selectively sensitive to human ostensive communication or whether selection for companionship is a prerequisite for the development of this skill, and what role experience with human communication plays.

On the one hand, domestication alone might have facilitated selective sensitivity to human ostensive communication in all domesticated animals, irrespective of their selection purpose. There is ample empirical evidence that even domesticated animals not selected for companionship readily follow human cues, such as directional cues (e.g., Nawroth et al., 2014, 2020). Even though these studies did not focus on sensitivity to ostension, the two skills are believed to be closely interrelated (Kaminski & Piotti, 2016; Miklósi & Topál, 2013; Prato-Previde & Marshall-Pescini, 2014; Topál et al., 2014). In addition, individuals that have undergone intensive socialization with humans but are not domesticated, such as apes, fail to follow human directional cues even when these are presented ostensively (Herrmann & Tomasello, 2006). Relatedly, results from dogs' wild relatives, wolves, suggest that exposure to human communication during ontogeny alone does not suffice to induce selective sensitivity to ostensive communication in non-domesticated species. For example, unlike dogs and human infants, human-reared wolves do not commit the A-not-B error after ostensive hiding (Topál et al., 2009). These findings seem to suggest that extensive exposure to human communication in itself does not induce animals' selective sensitivity to ostension. It remains unclear, however, whether domestication itself or selection for companionship can account for animals' sensitivity and whether and how exposure to human communication modulates the development of this skill in individual animals. Developmental studies on animals selected for companionship suggest that sensitivity to ostension emerges at a young age and does not significantly improve with increasing experience (i.e., age) with human communication and/or with the specific task (dogs: Byosiere et al., 2022; Kaminski et al., 2012; Pongrácz et al., 2005; cats: Pongrácz et al., 2019; horses: Proops & McComb, 2010).

On the other hand, even if not specifically focused on ostension, some studies have found effects of animals' age and/or closeness to humans on their success in following directional human cues in object-choice tasks (dogs and primates: Clark et al., 2019; horses: Liehrmann et al., 2023). Similar results exist for pigs. After testing pig populations varying in their experience with humans and the physical environment, Albiach-Serrano et al. (2012) come to the conclusion that developmental effects considerably influence domestic pigs' performance in social and physical cognition tests. Assuming that similar principles apply to animals' selective sensitivity to ostension, individual differences in the degree of exposure to human communication could still lead to heterogeneity within a species.

Due to their strong selection for companionship and intensive socialization, companion animals are likely to show a ceiling effect when tested for sensitivity to ostension. Therefore, researching exclusively these species is insufficient to disentangle the effects of domestication, selection for companionship and individual experience on animals' sensitivity to ostension, and data from domesticated species selected for other purposes is called for (see also Jardat & Lansade, 2022). Moreover, to better elucidate the origins of animals' sensitivity to human ostensive communication, Udell et al. (2009) and Miklósi & Topál (2013) suggest comparing less socialized domesticated animals with their intensively socialized conspecifics (e.g., companion animals). Taken together, an ideal candidate to shed light on the origins of animals' sensitivity to human ostension would be a domesticated species selected for purposes other than companionship in which individuals vary in their degree of socialization with humans.

1.4 The Domestic Pig and Its Interactions with Humans

Domestic pigs are highly suitable subjects for studying the origins of domesticated animals' sensitivity to human ostensive communication. Despite their long shared history with humans and unlike dogs or horses, they were not selected for companionship, but rather for meat production. Domestic pigs' ancestors were presumably attracted to human settlements by the ample food supply in the form of human waste, resulting in their domestication 9,000-10,000 years ago (Albarella et al., 2008; Lutwyche, 2019). With the onset of agriculture and sedentism, humans started to farm pigs for their meat and have selected them for growth ever since (Lutwyche, 2019). Still today, pigs are primarily kept for meat production but have begun to serve other purposes. In particular, pigs are nowadays frequently used in research and have also gained popularity as companion and zoo animals in recent years. This variety of different living environments and, concomitantly, degrees of socialization with humans, makes pigs ideal candidates to elucidate the impact of exposure to human communication on domesticated animals' sensitivity to human ostension.

In addition, pigs have proven very skillful in the few studies investigating interspecific interactions with humans. For instance, pigs can discriminate between individual humans (Koba & Tanida, 2001) as well as between the front and back of human heads (Wondrak et al., 2018). In the auditory domain, they can identify human voices (and prefer them to background noises) based on prosodic features (Bensoussan et al., 2019). Notwithstanding these remarkable capacities, pigs' reaction to human communicative signals has hitherto received little attention. Out of the few experiments that assessed pigs' ability to follow human pointing (Albiach-Serrano et al., 2012; Gerencsér et al., 2019; Nawroth et al., 2014, Wondrak et al., unpublished data), only Nawroth and colleagues (2014) found that pigs successfully follow human pointing in an object-choice task. However, no or only weak ostensive signals were used. Also, no direct comparison of pigs' reaction in ostensive versus non-ostensive contexts was undertaken. Hence, despite pigs' suitability for disentangling the effects of differential exposure to human communication on their selective sensitivity to human ostensive communication, the species' abilities in this domain have remained largely uninvestigated.

In the present study, we aimed to close this knowledge gap on pigs' selective sensitivity to human ostensive communication by subjecting three different pig populations (varying in their degree of exposure to human communication) to three tasks. We compared (a) miniature pigs kept as companion animals in Hungary (in collaboration with the Eötvös Loránd University, Budapest), (b) free-ranging Kune Kune pigs kept under semi-natural conditions for behavioral research and (c) breeding sows housed at a commercial pig farm. Unlike the majority of pig cognition studies, we decided to exclusively test adult, rather than juvenile, individuals. Therefore, we could expect our subjects to exhibit fully developed cognitive abilities, such as, potentially, sensitivity to human ostension. All three groups of pigs were tested in three paradigms previously applied to probe selective sensitivity to human ostensive communication in other species. The first one consisted in an **object-choice task with directional gaze cues**. Here, pigs' success in following the experimenter's gaze and body orientation to the correct location after ostensive and non-ostensive attention-getting were compared (similar to Kaminski et al., 2012). Second, the **A-not-B task** paradigm, previously used for dogs (Kis et al., 2012) and human infants (Topál et al., 2008), was adapted to pigs. In this task, dogs and human infants committed the so-called "A-not-B error" when, after having found a reward repeatedly in the same location that was indicated by conspicuous hiding, the reward was now hidden in a new location in an ostensive manner. In contrast to ostensive hiding contexts, dogs and infants did not make this mistake after non-ostensive hiding. We compared pigs' propensity to commit the A-not-B error between an ostensive and a non-ostensive condition. Finally, we tested pigs in a **detour task**, as in Pongrácz et al. (2004), to investigate the effects of ostensive and non-ostensive human demonstrations on the pigs' performance in reaching a target behind the fence.

These three tasks previously applied to companion animal species are expected to be suitable for pigs (with some modifications) given this species' advanced socio-communicative abilities and learning speed (Mendl et al., 2010). Nevertheless, considering that none of these tasks has been conducted with pigs, at least not specifically to probe sensitivity to human ostension, it is possible that pigs show such sensitivity only in some tasks but not in others, based on their species-specific characteristics. Our reporting of the results from three complementary tests will allow future studies to optimize their choice of methods when investigating socio-communicating skills in pigs. Additionally, combining the results of three different tasks will better equip us to determine in what exactly pigs' potential sensitivity to ostension consists. That is, whether pigs merely show increased attentiveness in ostensive conditions or whether, due to or independently of attentiveness, ostension also enhances their learning.

2. Research Questions and Hypotheses

We set out to investigate (1) whether human ostensive signals (compared with similar, non-ostensive ones) lead to enhanced learning in pigs and, if so, (2) whether this is likely due to increased attention or is facilitated by other mechanisms independent of attentiveness (like in dogs and infants (Duranton et al., 2017; Kis et al., 2012; Pongrácz et al., 2004; Topál et al., 2008, 2009)). Furthermore, we investigated to what extent these potential effects rely on pigs' individual exposure to and experience with human communication by comparing three groups of pigs. These were (a) pigs kept as companion animals, (b) free-ranging Kune Kune pigs experiencing daily contact and frequent training with humans for non-invasive behavioral research purposes and (c) commercial pigs experiencing less intense contact with animal keepers. We hypothesized that sensitivity to ostension would increase across the three groups as exposure to human communication increases. That is, we expected the commercial pigs to be least and the companion pigs to be most sensitive to ostensive communication. This could manifest, for example, in commercial pigs showing no sensitivity or only reacting to ostension with increased attentiveness, while companion pigs also show attentiveness-independent enhanced learning in ostensive contexts. We expected the lab pigs to take an intermediate position regarding their sensitivity to ostension.

3. Predictions

In regard to a potential effect of ostension, for each of the two hypotheses as well as the null-hypothesis (i.e., that pigs do not show any sensitivity to ostensive communication), predictions of how this tendency would manifest in each of the three tasks can be found in Table 1.

Table 1: Overview of hypotheses and respective predictions.

Task / **Hypothesis**	*No selective sensitivity*	*Increased attentiveness*	*Attentiveness-independent enhanced learning*
Object-choice task with gaze and body orientation	No differences in attentiveness and success between the ostensive and non-ostensive conditions	Higher proportion of time spent looking at the experimenter during cueing in the ostensive than in the non-ostensive condition	Higher success rate in the ostensive than in the non-ostensive condition when potential differences in attentiveness are controlled for
A-not-B task	No differences in attentiveness and probability of committing the A-not-B error between conditions	Higher proportion of time spent looking at the experimenter during the hiding in the ostensive than in the non-ostensive condition	Higher probability of committing the A-not-B error in the ostensive than in the non-ostensive condition when potential differences in attentiveness are controlled for
Detour task with human demonstration	No differences in attentiveness and latency to reach the target between conditions	Higher proportion of time spent looking at the experimenter during the demonstration in the ostensive than in the non-ostensive condition	Stronger decrease in latency (relative to the no demonstration trials) after ostensive than non-ostensive demonstrations when potential differences in attentiveness are controlled for

With regard to the effects of experience, we predicted that attentiveness and/or performance, also when controlled for attentiveness, should be highest in the companion pigs and lowest in the commercial pigs.

4. Methods

4.1 Ethical Approval

The part of the study conducted in Austria 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 (ethical permit number ETK-028/02/2023). The part of the study conducted in Hungary was approved by the responsible authorities at Eötvös Loránd University, Budapest (ethical permit No. PA/EA/112-2/2021).

4.2 Subjects

Three pig populations varying in their experience with and exposure to human communication acted as subjects, namely miniature pigs kept as companion animals (see 4.2.1 Companion Pigs), free-ranging Kune Kune pigs raised and kept in close contact with human caretakers for behavioral research (see 4.2.2 Free-Ranging Kune Kune Pigs Kept for Behavioral Research ("Lab Pigs")) and commercially farmed breeding sows kept for meat production (4.2.3 Breeding Sows Kept for Commercial Meat Production Purposes ("Commercial Pigs")). Their characteristics and keeping conditions are described below, an overview is also given in Table A1 in the appendix.

4.2.1 Companion Pigs

Eight mixed-breed companion pigs, four males and four females, participated in the present study. Seven of them are part of a long-term project by the Department of Ethology at the Eötvös Loránd University in Budapest, Hungary. In the course of this project, the animals were adopted by human families at approximately eight weeks of age to allow for a socialization similar to family dogs' (Gerencsér et al., 2019; Pérez Fraga et al., 2021). By the time of testing, the companion pigs were between four and five years old. These seven pigs are all housed individually, i.e., they are and have been the only pig (but not necessarily the only pet) in the household.

The eighth pig was recruited from a population of seven miniature pigs kept in the same household. This seven-year-old individual regularly participates in animal-assisted interventions and other events that involve contact with unfamiliar humans. Given that this pig is used to frequent travelling, it was the only one from the companion pig group not to be tested at home but in an experimental room at Eötvös Loránd University.

The companion pigs had previously participated in experiments on human-pig communication, for example an object choice-task with pointing cues (Gerencsér et al., 2019), an out-of-reach paradigm probing human-oriented referential communication (Pérez Fraga et al., 2023) as well as an unsolvable task (Pérez Fraga et al., 2021).

4.2.2 Free-Ranging Kune Kune Pigs Kept for Behavioral Research ("Lab Pigs")

This group comprised 34 (17 females, 17 vasectomized males) free-ranging Kune Kune pigs, out of which 31 (16 females, 15 males) participated in at least one task (hereinafter referred to as "lab pigs"). The remaining three were excluded and/or only used for piloting due to deafness. The pigs were between seven and ten years old at the time of testing.

These pigs were raised for the purpose of behavioral research at the Haidlhof Research Station, Bad Vöslau, Lower Austria, and kept under semi-natural conditions, as one multi-male/multi-female sounder until October 2022. Then the whole group of pigs was moved to Gut Aiderbichl, Henndorf am Wallersee, Salzburg, Austria, where all of them will remain until their natural death. The 5 ha pasture at Gut Aiderbichl is equipped with two A-shaped wooden huts for shelter as well as a mobile drinker and a muddy wallow. A stable (200 m²), where drinkers, beddings with rubber mats and deep straw, and a tar-covered feeding place (50 m²) are located, offers shelter from snow in winter and sun in summer. Access to the pasture is not restricted. In winter, hay as roughage is offered *ad libitum*. The animals have always had daily contact with animal keepers (feeding and health check), and are used to the presence of researchers since they have participated in various behavioral and cognitive studies in the past. Among these are a pointing task (Wondrak et al., unpublished data) and a study on social learning including human demonstrations (Veit et al., 2023). Further, they were already tested in a previous detour task (Nestelberger, 2019), albeit in the absence of any human demonstration.

All pigs are trained to respond to their individual names when called and follow the experimenter voluntarily to the test enclosure. Also in the present study, they were always rewarded for following the experimenter's requests (positive reinforcement only).

4.2.3 Breeding Sows Kept for Commercial Meat Production Purposes ("Commercial Pigs")

This group of pigs most adequately represents the majority of domestic pigs living in human care today, as they were and are kept for meat production. Twenty breeding sows (one to three years old, Large White, Swiss Genetics) housed at the teaching farm Vetfarm Medau in Berndorf, Lower Austria, were included in the study, out of which 15 ultimately participated in at least one task (hereinafter referred to as "commercial pigs"). According to the standard procedures at the Vetfarm, the pigs are housed in groups in indoor pens with partly slatted floors. For the duration of the study, pigs were accommodated in smaller groups of two to five individuals in partly slatted floor pens (size: 879 cm × 493 cm for larger groups or 879 cm × 245 cm for smaller groups). Pigs were automatically fed three times a day and had *ad libitum* access to water in drinkers. We conducted the tests in an adjacent pen that resembled the home pen.

Pigs were kept according to the routine procedures at the Vetfarm, meaning that they were checked upon daily and received medical treatment whenever necessary. After the end of the study, the sows continued to be used for breeding and meat production purposes.

Prior to this study, the commercial pigs had experienced limited daily human contact with animal keepers as well as researchers, veterinary students and teachers. Unlike for the lab pigs, these experiences were mainly neutral or, in some cases, could even be perceived as mildly negative by the animals (e.g., students exercising veterinary practices). This group has not specifically been trained to cooperate with humans and they have, to our knowledge, no or only very limited experience with behavioral testing.

4.3 Test Arena

In the case of the companion pigs, all tests were conducted in their owners' gardens, or, as an exception for one pig as outlined above, at the university. All gardens (or parts of the garden in which the tests were conducted) were at least 3.5 m × 3.5 m in size. The tests were conducted on the uncovered lawn present in the gardens with other objects such as furniture or toys etc. surrounding the arena. Family members not directly participating in the test (i.e., everyone except the person releasing the pig from the start box) and assisting researchers were asked to watch quietly from a distance or leave the garden and to ensure that other pets did not interfere with the tests.

We tested the lab pigs in two different test enclosures (one for the object-choice and A-not-B tasks, approximately 300 cm × 300 cm in size, and a separate one for the detour task, approximately 600 cm × 450 cm in size) consisting of metal fences. The floor and the sides of the arena were covered by green tarpaulins to minimize distraction by grass and other pigs.

For the commercial pigs, tests took place in an empty indoor pen (879 cm × 245 cm) with a partly slatted floor.

In all three tasks, pigs watched the experimenter's demonstrations from a start box, from which they were later released into the test arena. This start box consisted of fences or wood set up in a round or square shape with a diameter/length of approximately 150 cm for the companion pigs, 180 cm for the lab pigs, and 200 cm for the commercial pigs.

4.4 Habituation

For the purpose of familiarizing them with the novel environment (in the case of the commercial and lab pigs) and with the experimenter, the pigs underwent a habituation session prior to the test sessions.

In the case of the companion pigs, the experimenter visited the pigs at home at least once on a separate occasion before the first test. In the presence of the owner, the experimenter invited the pigs for positive interactions (such as gentle stroking). For pigs that showed fearful or aggressive behavior towards the experimenter, such habituation visits were repeated until the pig ceased to show signs of aggression or distress (beyond the level reported as typical by the owners) in the presence of the experimenter.

For the lab and commercial pigs, the habituation phase consisted of 10-min sessions in the test enclosure. The pigs were individually guided to the test enclosure by the experimenter (using a food reward if necessary). First, they were allowed to explore the enclosure on their own for one minute. After one minute, the experimenter entered and offered positive interactions (e.g., gentle stroking) to the pigs by allowing them to approach her voluntarily. After another minute, the experimenter tried to approach (if the pig had not already approached her in the previous phase) and pet the pig during the subsequent 6 min. In the last two minutes, pigs again had the opportunity to explore the enclosure on their own.

We conducted three such habituation sessions on three separate (not necessarily consecutive) days with the commercial pigs. Due to their experience with testing, the lab pigs only underwent one habituation session.

None of the lab or commercial pigs showed distress, aggression or aversion to being touched by the experimenter.

4.5 General Procedure

Before each trial in each task, the experimenter used food to reward the pig if it had followed the human to the start box from where it could observe the experimenter's actions and be released into the testing area at the start of the trial. The pigs were familiarized with this start box during the warm-up trials of the first task, the object-choice task (see 4.6.1 Task 1: Object-Choice Task with Directional Gaze and Body-Orientation Cues).

To keep the pig in the start box during the demonstration and to subsequently release it, either the pig's owner (for most companion pigs) or an assistant stood inside (companion pigs) or next to (lab and commercial pigs) the start box during the tests. After each trial, the owner/assistant and/or the experimenter lured the pig back to the start box using a food reward.

The pigs completed three different tasks in the same order for each individual. All subjects first experienced all conditions (ostensive, non-ostensive, control) of the object-choice test in one session (Session 1). After a break of at least three days, they were tested in the first condition of the detour task and afterwards in the first condition of the A-not-B task (Session 2). This first condition (i.e., ostensive or non-ostensive) was the same in both tests. On the third day (after another break of at least three days), the other condition (i.e., ostensive if the individual pig had experienced the non-ostensive condition first – or vice versa) of these two tests were conducted (Session 3). Due to experimenter error, sessions 2 and 3 were only 2 days apart (i.e., session 3 was conducted on the third day after session 2) for two lab pigs.

Which condition came first for the detour and A-not-B task, i.e., the condition that came second in the object-choice task, was counterbalanced across subjects (see first five columns of Table 2). In addition, the order of conditions and the correspondence of the set-ups to the conditions was also counter-balanced across sexes for the lab pigs, which is not depicted here (but see Table A1 in the appendix).

Table 2: Overview of the experimental design showing the counterbalancing of conditions and set-ups across eight example subjects. "O" stands for the ostensive condition and "N" stands for the non-ostensive condition (the control condition of the object-choice task is not included here as it always came third). "L" stands for left, "R" for right, "J" for the J-shaped set-up of the detour and "MJ" for the mirror-image J-shaped set-up of the detour. For details about columns 6 to 10 see descriptions of the tasks in the following sections.

Subject	Object-choice task first condition	Object-choice task second condition	A-not-B and detour tasks first condition	A-not-B and detour tasks second condition	" A" side	A-not-B set-up first condition	A-not-B set-up second condition	Detour set-up first condition	Detour set-up second condition
1	O	N	N	O	L	Plastic	Carboard	MJ	J
2	N	O	O	N	R	Plastic	Cardboard	J	MJ
3	O	N	N	O	R	Cardboard	Plastic	J	MJ
4	N	O	O	N	L	Cardboard	Plastic	MJ	J
5	O	N	N	O	R	Plastic	Cardboard	J	MJ
6	N	O	O	N	L	Plastic	Cardboard	MJ	J
7	O	N	N	O	L	Cardboard	Plastic	MJ	J
8	N	O	O	N	R	Cardboard	Plastic	J	MJ

To minimize the risk of carry-over effects between conditions in the A-not-B and detour tasks, we a) conducted the three test sessions on separate days with at least 3 days in between, b) used slightly different set-ups in the two conditions (see below) and c) rotated the testing arena (i.e., also the starting point) by 90–180° relative to the orientation in the first condition for the companion and lab pigs. Rotating the arena was not possible for the commercial pigs due the layout of the pen.

The same experimenter conducted all tests with all pig groups.

4.6 Tasks

4.6.1 Task 1: Object-Choice Task with Directional Gaze and Body-Orientation Cues

In the first task, pigs could find food in one of two food bowls if they followed the experimenter's gaze and body orientation cues directed at the baited location.

Materials and Set-up

Two bowls were placed in front of the start box, 130 cm apart from one another (as in: Byosiere et al., 2022). The orthogonal distance between the start box and the bowls amounted to approximately 1.5 body lengths (estimated average body length of the respective pig group). For exceptions see Appendix A and Table A1. The experimenter was kneeling approximately 40 cm behind the imaginary midline, equidistant from both bowls (similar to: Nawroth et al., 2014). Between the experimenter and the bowls (and the pig, once it had approached the bowls) a low barrier (approximately 30 cm high for the companion pigs, 40 cm high for the lab pigs and 60 cm high for the commercial pigs) was placed to give security to both the experimenter and the pigs (Figure 1B-D). The experimenter was kneeling in an elevated position (i.e., on a 20-cm high children's car seat or on a 50-cm high stool) behind this barrier for the lab and commercial pig tests. All the sessions were recorded using two cameras (Figure 1A).

One of the bowls (approximately 30 cm in diameter) contained a reward (e.g., apple pieces or carrots, depending on the owner-reported preferences of the pig). Each of these bowls had a double bottom hiding additional food (equal amounts on the two sides) in order to control for olfactory cues. In addition, both bowls were rubbed in food scent prior to the session. In early warm-up trials, which were executed to establish the bowls as a food source, the bowls were presented without a cover, so that the pig could see inside and determine visually if a reward could be obtained. From warm-up trial 6 onwards and in all test trials, the bowls were covered (with cardboard or wood) to prevent the subjects from seeing from a distance which of the bowls was baited with a piece of reward that was accessible to the pigs.

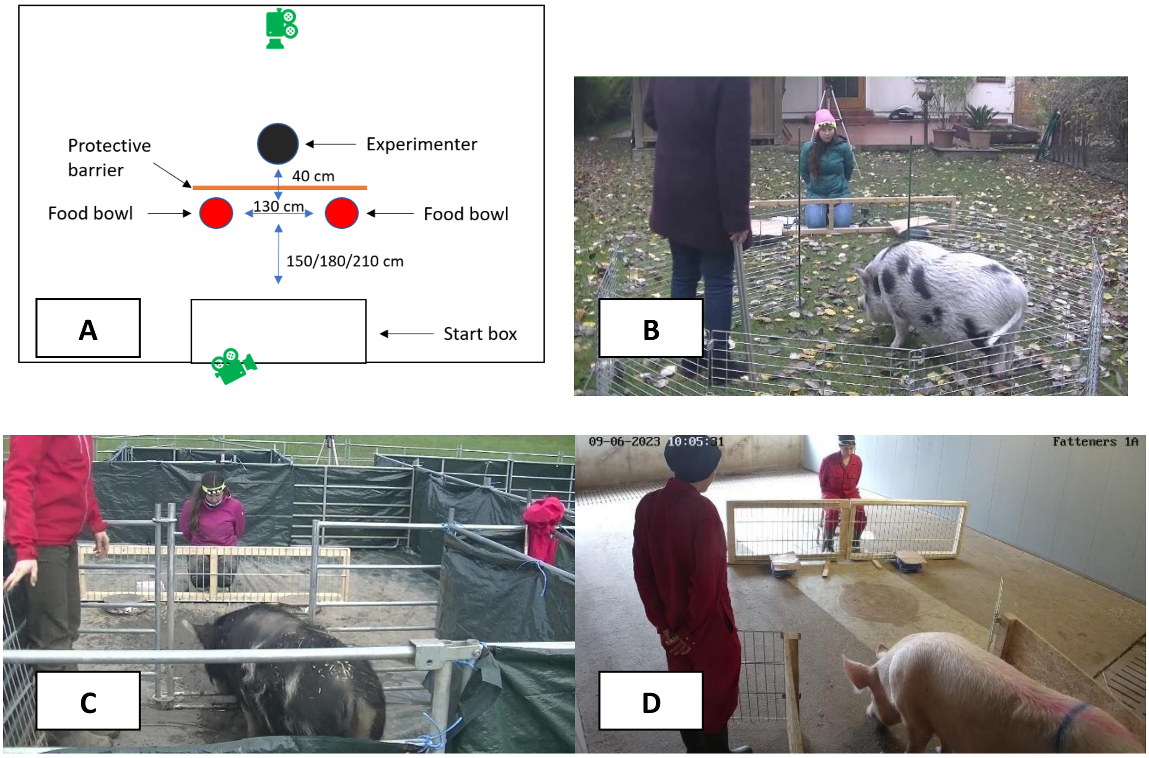

Figure 1: A: Schematic overview of the experimental set-up in the object choice task (top view), including the position of the cameras (in green). B: Picture of the set-up for the companion pigs. C: Picture of the set-up for the lab pigs. D: Picture of the set-up for the commercial pigs.

Warm-up Trials

Before the test trials, pigs were made aware of the possibility that each of the bowls could contain food. For this purpose, they experienced at least ten warm-up trials, with equal numbers of trials on each side. The sequence of trials was semi-random in a way that the food was not hidden on the same side in more than two consecutive trials. Before each trial, the experimenter or the owner/assistant lured the subject to the start box. The experimenter then called the subject’s name or a familiar command to attract its attention and showed the food reward before openly placing it into one of the bowls as soon as the subject looked at her. In the subsequent trials, the covers were also placed on the bowls so that the subject could learn how to remove them to access the reward. After the baiting, the subject was released and was free to investigate both food bowls. The warm-up was deemed successful if a pig approached at least one of the bowls (i.e., not necessarily the correct one first) and eventually found the food within 30 s after leaving the start box in at least eight out of the ten last trials. Once a pig passed the criterion, it proceeded to the test phase. If a pig did not reach the success criterion after 20 warm-up trials, we terminated the session and started anew with the first warm-up trial on another day. If three warm-up sessions were unsuccessful due to the pig not reaching the criterion, we excluded this pig from the study.

Test Trials

Each subject underwent 12 test trials, in two blocks of six, i.e., one block per condition (ostensive/non-ostensive). The order in which the conditions were presented was semi-randomly selected and counterbalanced across subjects (see Table 2). In addition, six control trials in which the experimenter did not provide any cues were conducted at the very end of the session to control for other, unintentional, cues. After the warm-up trials, the subject immediately proceeded to the first block of trials. After a break (min. 5 minutes), the second block/condition was conducted, and another break was held before the control trials. For each condition, the food was hidden in the right bowl in half of the trials and in the left one in the other half of the trials, in a semi-random order. The food was not hidden in the same bowl more than twice in a row to prevent the formation of a side bias.

Before each trial, the experimenter hid the food in one of the bowls out of the pig's view (e.g., behind her back or while the pig was facing away from her). She then placed the bowls in front of the barrier and covered them. As soon as the bowls were in place, the experimenter attracted the subject's attention (ostensively or non-ostensively, depending on the condition, see Figure 2A).

In the ostensive trials, the experimenter established eye-contact with the subject and called the subject's name or a familiar command.

As soon as the pig looked at her, she gave three momentary, dynamic gaze and body orientation cues (Figure 2B) before the owner/assistant released the subject from the start box. The gaze cues involved a change in body orientation, i.e., not just the experimenter's eyes and head but also her shoulders turned towards the correct food bowl.

In the non-ostensive trials, the experimenter pretended to play with three bells on her forehead attached to a ribbon worn around her head before each gaze cue, resulting in potentially attention-eliciting sounds and similar movements as in the ostensive condition. In between the directional cues, the experimenter did not look at the subject but instead upwards, at the bells.

In the control condition, the experimenter remained immobile and looked down on her lap instead of at a bowl or the subject. The subject was released as soon as the experimenter had lowered her head.

To allow for consistency of the experimenter's appearance across conditions, the experimenter also wore non-functional mock bells in the warm-up trials, ostensive trials and control trials.

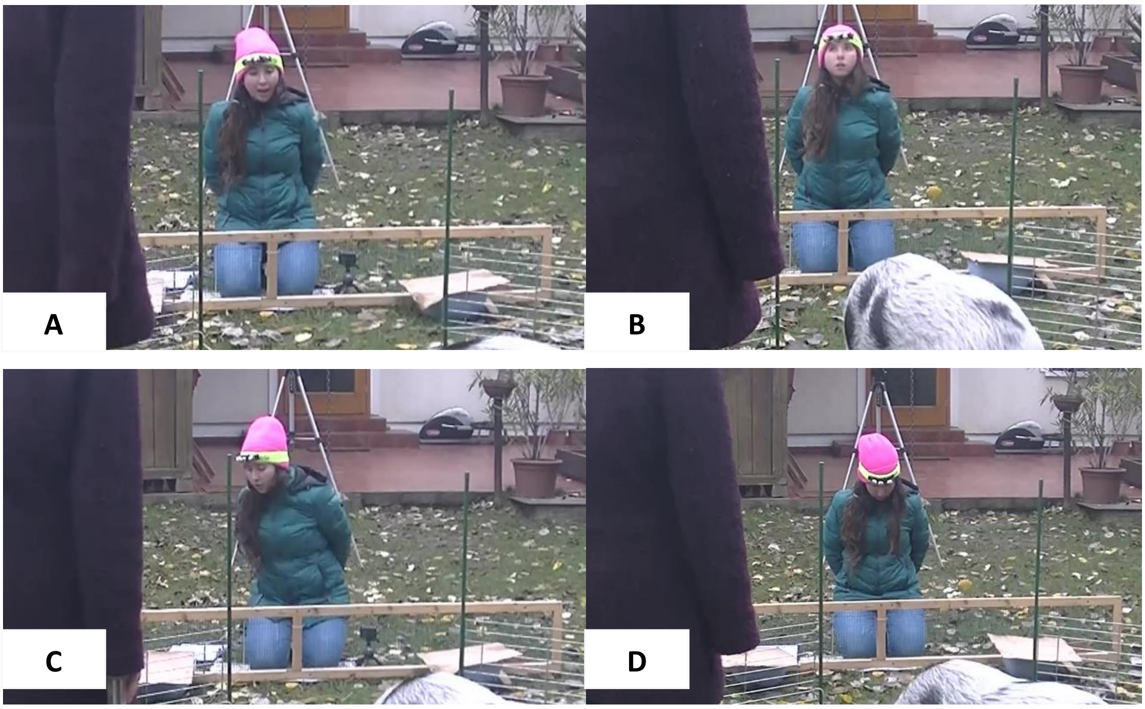

Figure 2: A: Ostensive attention-getting: the experimenter called the subject's name or a familiar command while seeking eye-contact with the pig. B: Non-ostensive attention-getting: the experimenter rang bells worn on her head while looking upwards and focusing on the bells. C: Directional cue in both the ostensive and non-ostensive conditions: after each of three ostensive or non-ostensive attention-getters, the experimenter gazed at and bent towards the baited bowl. D: In the control condition, the experimenter did not give any directional cues or attention-getters.

A trial ended either when the subject had made a choice or 30 s after its release. After each trial, the subject was guided back to the start box either by the experimenter or by the owner/assistant.

Trials in which the subject did not make a choice were repeated. Whenever a subject failed to make a choice in three consecutive trials, the test session was terminated and continued on another day. Likewise, signs of distress displayed by the subject would have led to the interruption of testing.

4.6.2 Task 2: A-not-B Error Task

In the second task, we assessed whether ostension increases pigs' attentiveness and/or enhances pigs' tendency to commit the A-not-B error in an A-not-B task.

Materials and Set-up

The test was conducted in the same test arena as the object-choice task. As in the object-choice task, the subject was able to observe the experimenter's actions (when she was hiding the food reward) from the start box before being released.

To allow for each subject to be tested in both conditions (ostensive, non-ostensive) while minimizing the risk of carry-over effects, two slightly different set-ups (occluders) were used. In one variant, two opaque blue plastic screens acted as potential hiding locations. Alternatively, two unfolded cardboard boxes were set up as V-shaped hiding locations. In the following, both will be referred to as "screens". Which set-up was used in which condition was counter-balanced across subjects (see Table 2). The screens were placed at a distance of 150 cm from one another. The distance from the start box was the same as in the object-choice task, i.e., approximately 1.5 body lengths (estimated average body length of the respective pig group, see Figure 3A). The target that the experimenter hid behind one of the screens always was a conspicuous (e.g., blue) or familiar (already associated with food) bowl baited with food.

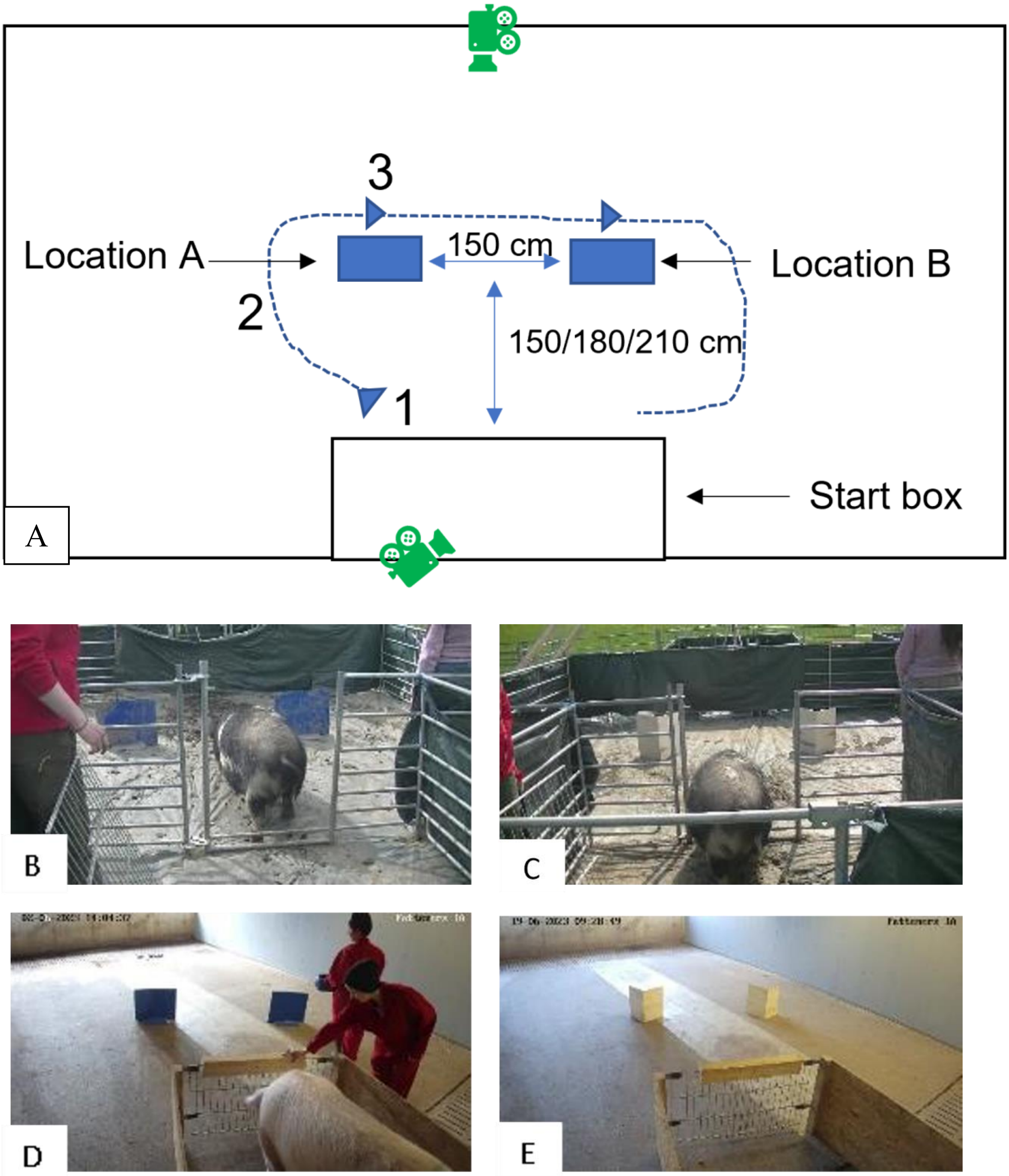

Figure 3: A: Schematic overview of the set-up in the A-not-B task (top view,) including the position of the cameras (in green). The numbers 1-3 indicate where the three ostensive or non-ostensive utterances were given. In this example, the blue plastic screens (rather than the cardboard) are used and location A is to the subject's left. B: Example of the plastic screen set-up for a lab pig. C: Example of the cardboard set-up for a lab pig. D: Example of the plastic screen set-up for a commercial pig. E: Example of the cardboard set-up for a commercial pig. For an example of the companion pig set-up see Figure 4.

Test Procedure

Each subject experienced both an ostensive and a non-ostensive condition on two separate testing days that were at least 3 days apart. For one of these conditions, the blue plastic screen set-up was used while the other condition was implemented using the cardboard screens. In addition, the arena was rotated by 90-180° in the second session for the companion and lab pigs, relative to the spatial arrangement in the first one. Which condition was paired with which set-up was counter-balanced across subjects, so was the side of the locations “A” (the location in which the food is hidden first) and “B” (see Table 2). However, whether location “A” was left or right was constant across conditions for each individual subject.

Each block/condition consisted of the following sequence of trials: A – A – B – B – A (hereinafter referred to as A1, A2, B1, B2 and A3). No designated warm-up trials were conducted for this task, however, a pig only proceeded to the B trials once it had successfully approached location A first and found the food in two consecutive A trials. Otherwise, the A trials were repeated up to 30 times. After this, hiding at location B followed twice before a final A trial.

The purpose of the final A trial was to assess whether pigs’ (potential) perseveration persists even after the B trials. Depending on the condition, the hiding in all trials of a block took place ostensively or non-ostensively.

Before the start of each trial, the target (i.e., the baited food bowl) was with the experimenter who was standing next to the start box and the subject was inside the start box.

In the A trials, the experimenter first crouched in front of the entrance of the start box, showed the food to the subject (including making sounds with the food/the bowl) and made the first ostensive or non-ostensive utterance (see Figure 4A and E). The experimenter then walked to screen A to deposit the target. On her way to location A, she uttered the second ostensive or non-ostensive attention-getter (Figure 4B and F) and the third one followed while she crouched and put down the bowl (Figure 4C and 4G). She then continued her path past location B. As soon as the experimenter had reached her final position on the other side of the start box), the subject was released from the start box.

In the B trials, the experimenter repeated the same procedure, i.e., also started on the A side, passed by and sham-baited location A first (crouching and moving the food bowl behind the screen), but subsequently hid the target in location B (see Figure 4D and H). The number and timing of ostensive or non-ostensive attention-getters stayed the same as in the A trials, i.e., no fourth attention-getter was uttered when placing the bowl behind screen B.

The ostensive and non-ostensive conditions differed in several regards. First, the experimenter faced the subject in the ostensive condition (i.e., turned around and established eye-contact) when she uttered the attention-getters (Figure 4A-D). In contrast, she faced away from the subject (turned her back on the subject) in the non-ostensive condition (as in Topál et al., 2009; Figure 4E-H) and did not establish eye-contact. We expected this to create a clear contrast for the pigs, considering that pigs were shown to be able to discriminate between the front and back of human heads (Wondrak et al., 2018). Second, the experimenter addressed the subject by name or used a familiar command in the ostensive condition, while she pretended to talk to herself (saying “Where could I hide the food?”) in the non-ostensive condition.

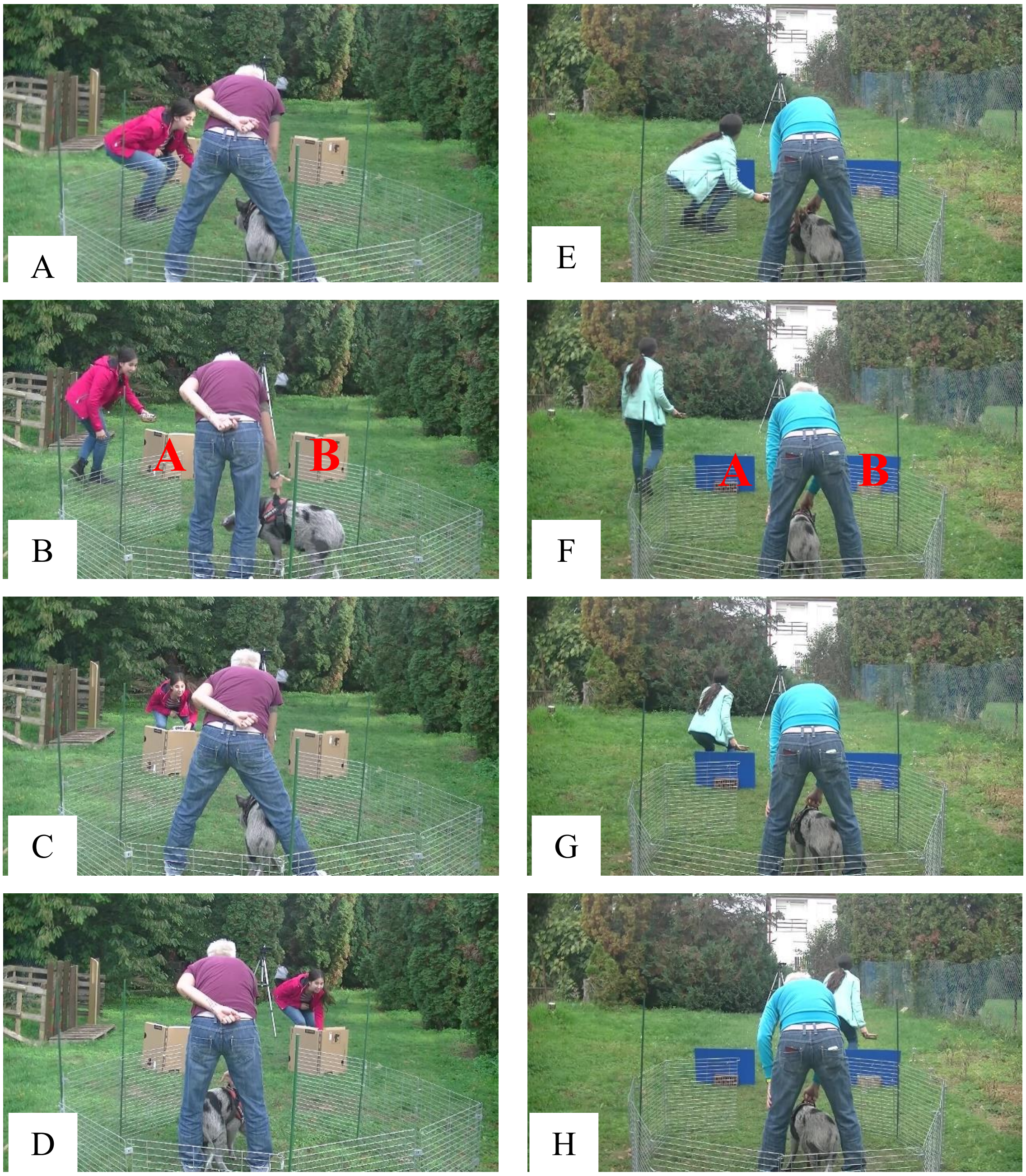

Figure 4: Procedure in the A-not-B task. A-D: Example of an ostensive B trial with the cardboard set-up for a companion pig. A: First ostensive utterance in front of the start box. B: Second ostensive utterance. C: Third ostensive utterance and (sham) hiding of the bowl behind screen A. D: Hiding of the bowl behind screen B (only in B trials). E-H: Example of a non-ostensive B trial with the plastic screen set-up for a companion pig. E: First non-ostensive utterance in front of the start box. F: Second non-ostensive utterance. G: Third non-ostensive utterance and (sham) hiding of the bowl behind screen A. H: Hiding of the bowl behind screen B (only in B trials).

After the subject was released from the start box, it was allowed to inspect both locations and eat the food even if it approached the incorrect location first (as in Gergely et al., 2016; Péter et al., 2015). However, only the subject's initial choice was recorded (see below). A trial ended after the subject had made a choice or 60 s after the subject's release from the start box. The subject was guided back to the start box after each trial. Trials in which the subject did not make a choice were repeated up to three times. Testing was terminated if the subject still did not make a choice the third time.

4.6.3 Task 3: Detour Task with Human Demonstration

Inspired by Pongrácz et al.'s (2004) study on dogs, we compared pigs' ability to learn the correct route around a detour from a human demonstrator after an ostensive and a non-ostensive demonstration.

Materials and Set-up

To allow us to test each individual in more than one condition, the arena was rotated by 90-180° in the third session (second detour session) relative to the set-up of the second session (first detour session) for the companion pigs and two different detour set-ups were used for the two sessions/conditions for all pig groups. Both were built from portable metal fences (companion pigs) or robust metal fences with a wooden frame (lab and commercial pigs). The two different arrangements of the fence were a J-shaped inward detour and a mirror-image J-shaped inward detour (see Figure 5). In inward detour tasks, subjects start on the outside and need to make their way to the target on the *inside* of a (form their perspective) convex fence (Kabadayi et al., 2018). Our reason for not exactly replicating Pongrácz et al. (2004) who used a V-shaped detour was that the Kune Kune pigs had already been tested on a V-shaped detour task in a previous study (Nestelberger, 2019), albeit without any demonstration.

Which condition, ostensive or non-ostensive, was combined with which set-up (J or mirror-image J) was counterbalanced across pigs. However, pigs whose A side was on the left in the A-not-B task experienced the mirror-image J first (for which the shorter arm, i.e., the side of the demonstration, was on the right) and vice versa (see Table 2).

The total length of the fence was approximately 600 cm for the companion pigs, 610 cm for the lab pigs and 735 cm for the commercial pigs. The vertex of the J was approximately 150 cm away from the start box. The length of the longer arm of the J (measured from the inside of the vertex to the imaginary line perpendicular to the end of the long arm) amounted to 42% of the overall fence length, the length of the shorter arm amounted to 28% of the overall fence length.

The width of the fence was 41% of the entire fence length. The fence was approximately 60 cm high in all cases.

Given pigs' strong natural propensity to root and lift objects with their snout (Studnitz et al., 2007), the fence was fixed in place for the companion and lab pigs by anchoring it in the ground. This was not possible in the indoor arena in which the commercial pigs were tested.

A familiar food bowl or, if no familiar bowl was available, a particularly conspicuous (e.g., big and blue) food bowl acted as the target. In both set-ups, it was positioned directly behind the inside of the vertex.

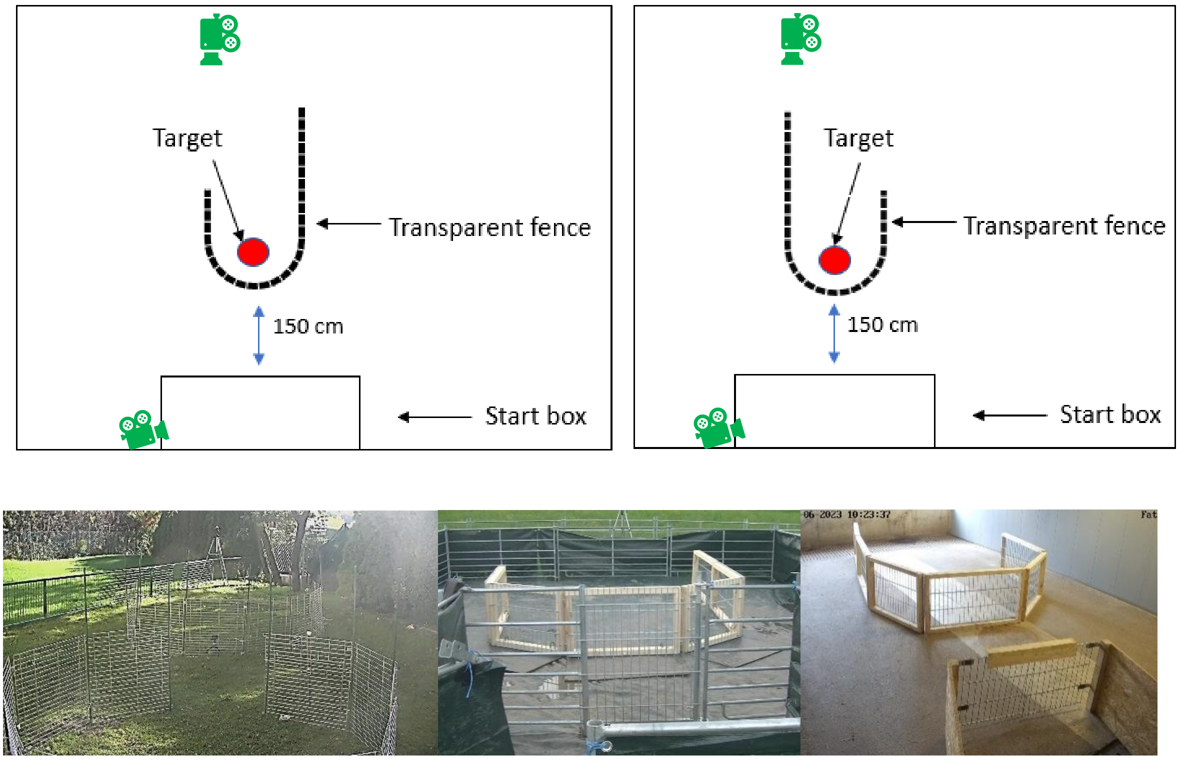

Figure 5: Schematic overview of the two set-ups in the detour task (top view), including the position of the two cameras (in green). Left: J-shaped detour; right: mirror-image J-shaped detour. Example pictures of the detour set-ups for the companion pigs (left), lab pigs (middle) and commercial pigs (right).

Warm-up Trials

To train the pigs to look for the target, the food bowl, we conducted one warm-up trial per condition. In these trials, the experimenter placed the food bowl in front of the fence. Therefore, the pig did not have to detour the fence yet to reach the target. The pigs were expected to directly approach the target upon being released from the start box. If a pig failed to eat the food from the bowl within 30 s, the warm-up trial could be repeated up to five times. In the event of five unsuccessful warm-up trials, the session was resumed on another day (up to three times, otherwise the pig would have been excluded), again starting with a warm-up trial. In these repeated warm-up trials, the distance between the pig and the food bowl could be decreased if needed.

In the warm-up trials, the experimenter crouched in front of the pig, showed the food in the bowl to the pig, and made sounds with the food/the bowl before placing the bowl in front of the fence. The experimenter did not talk in the warm-up trial(s).

Test Trials

Each pig experienced a total of six test trials per condition, i.e., a sum of 12 trials on two separate days. Each block of trials consisted of three unaided trials ("no-demonstration" trials) in which the pigs were given up to 1 min to solve the detour task on their own, without any demonstration. In the three last trials of a session, the experimenter performed an ostensive or non-ostensive demonstration of the detour by walking around the shorter end of the barrier.

In the no-demonstration trials, the experimenter showed the food bowl to the pig and made sounds with it/the food before lifting it above the fence from the outside (at the vertex of the J). The experimenter then reassumed her position next to the start box and the subject was released. It could then try to find its way to the target around the barrier.

In the demonstration trials, the experimenter crouched and showed the food to the subject as in the no-demonstration trials but additionally uttered the first ostensive (Figure 6A) or non-ostensive (Figure 6D) attention-getter. While carrying the target around the shorter end of the fence, she either talked to the subject another two times, addressing it by name or saying a familiar command like "Come!" (ostensive condition, see ostensive attention-getters for the A-not-B task described above), or talked to herself two more times (saying "Where could I hide the food?"). The experimenter uttered the second attention-getter mid-way to the end of the short arm (see Figure 6B and E) and the last one when she reached the end of the fence (see Figure 6C and F), i.e., before she entered the "inside" of the J/mirror-image J. In both cases, while talking, she turned her head and look around – either in the direction of the pig and established eye-contact (ostensive condition, see Figure 6B and C), or in another direction (non-ostensive condition, see Figure 6E and F). After putting down the bowl behind the fence and walking back on the same route, she re-assumed her position next to the start box and the pig was released.

Figure 6: Example of an ostensive detour demonstration (A-C) and a non-ostensive detour demonstration (D-F) in the moments in which the experimenter gives each of the three attention-getters. A: Experimenter crouches and utters the first ostensive attention-getter in front of the start box. B: Experimenter turns around mid-way and utters the second ostensive attention-getter. C: Experimenter utters the third ostensive-attention getter while walking around the shorter arm of the mirror-image J. D: Experimenter crouches and utters the first non-ostensive attention-getter in front of the start box. E: experimenter utters the second non-ostensive attention getter while looking around, without turning to the pig. F: Experimenter utters the third non-ostensive attention getter, without turning to the pig, while walking around the shorter arm of the mirror-image J. Note that the pictures of the non-ostensive trial are taken from the front to allow for better visibility of the experimenter's body orientation.

A trial ended as soon as the subject had reached the target (i.e., touched the bowl) or after 1 min. The subject was then guided back to the start box.

If the subject a) did not leave the start box within 30 s once, b) left but did not approach the fence (within one head length), i.e., went away, in two consecutive trials or c) approached the fence but did not stay in proximity (one head length) to the fence for longer than 10 s and did not return to the fence in two consecutive trials, a motivational trial (identical to the warm-up trials) was interspersed. Testing was terminated if a pig failed to retrieve the food in 5 consecutive motivational trials.

4.7 Behavioral Coding

All sessions were video recorded. The behaviors listed in Table 3 were later extracted from the videos using Loopy coding software (http://loopb.io, loopbio gmbh, Vienna, Austria).

Table 3: Ethogram containing the variables that were coded and analyzed in the three tasks.

Variable	*Description*	*Task(s) for which behavior was coded*
Attentiveness	Pig's snout is oriented within the imaginary triangle between the center of its head (approximately a point between its ears) and the two bowls (object-choice task) or the two screens (A-not-B task). This is not coded if the pig is visibly occupied with something else (e.g., pushing the door of the start box, grazing) or is looking up at the owner/assistant (with its snout being higher than the horizontal).	Object-choice task, A-not-B task
Attentiveness (Detour)	Pig's snout is oriented within the imaginary triangle between its head, the vertex of the fence and 1 m on the outside next to the side of the fence detoured by the experimenter. This is not coded if the pig is visibly occupied with something else (e.g., pushing the door of the start box, grazing) or is looking up at the owner/assistant (with its snout being higher than the horizontal).	Detour task
Cueing duration	Time between the last attention-getter preceding the first of the three directional cues and the end of the last directional cue (when the	Object-choice task

	experimenter has re-assumed an upright position).	
Demonstration duration	Time between the first cue the experimenter utters in front of the start box[1] and the pig's release from the start box with release being defined as the first moment the door is open wide enough so that the pig can comfortably fit through without squeezing or bending.	A-not-B task, detour task
Relative attentiveness	Attentiveness divided by the cueing duration (object-choice task) or the demonstration duration (A-not-B and detour tasks).	All tasks
Success	Pig touches the correct (i.e., baited) bowl (object-choice task) or screen (A-not-B task) before the incorrect one within 30 s upon being released.	Object-choice task, A-not-B task
Success (Detour)	Pig touches the target (bowl behind the fence) within 60 s upon being released.	Detour task
Latency to reach target	Time between the pig's release from the start box and the moment it first touches the bowl. The maximum latency, 60 s, was assigned to pigs that had not reached the target by the end of the trial.	Detour task

[1]Note that the start of the demonstration was defined differently for the commercial pigs due to the unavailability of sound on these recordings. For this group, the start of the demonstration was defined as the last moment the bowl the experimenter was carrying touched the ground during the first utterance (in which the experimenter also moved the bowl to attract the pig's attention).

4.7.1 Inter-Rater Reliability Analysis

A second observer independently coded 20% of the trials, proportionally split across all tasks and groups, to assess inter-rater reliability.

We calculated the inter-rater reliability for the variables relative attentiveness (all tasks), success (all tasks), detour side (detour task) and latency to reach the target (detour task) using the R package irr version 0.84.1 (Gamer et al., 2019). In case of the variables success and detour side, we calculated Fleiss' Kappa (κ), while the intraclass correlation coefficient (ICC, set to "consistency") was calculated for the variables relative attentiveness and latency to reach the target.

Agreement was almost perfect for the variable success in the object-choice (κ = 0.966, n = 178) and A-not-B tasks (κ = 0.956, n = 100) and the two raters agreed perfectly for the success (κ = 1, n = 119) and side (κ = 1, n = 50) in the detour task. Regarding the relative attentiveness, the reliability was very good to excellent for the object-choice task (ICC = 0.871, n = 129), the A-not-B task (ICC = 0.898, n = 100) and the detour task (ICC = 0.851, n = 66). The raters also agreed very strongly on the latency to reach the target in the detour task (ICC = 0.996, n = 119).

4.8 Statistical Analyses

All analyses were performed in R version 4.3.0 (R Core Team, 2022). For each of the three tasks, we analyzed the two main response variables attentiveness and success (latency, in the case of the detour task). We did so by fitting a full model for each response variable in each task that contained all fixed effects of interest as well as control and random effects. In all cases, this full model was compared with a null model which lacked the main fixed effects of interest but was otherwise identical to the null model. We used a χ^2-test (anova function, package stats version 4.3.0 (R Core Team, 2022)) to compare the full model with the null model (Forstmeier & Schielzeth, 2011). To investigate significant differences more closely, we employed the drop1 function and reduced models to test the significance of interactions and single terms (Barr et al., 2013). To calculate pairwise differences between levels of a factor we used the functions emmeans and pairs within the emmeans package version 1.8.7 (Lenth, 2022). The full models are reported in more detail in the following sections.

In addition, to compare the length of the cueing/demonstration between the ostensive and non-ostensive condition in all tasks, we conducted Mann-Whitney U-tests.

4.8.1 Analysis Object-Choice Task

We compared pigs' attentiveness to the experimenter's cues (i.e., the relative attentiveness calculated by dividing the time spent attentive by the duration of cueing) between the ostensive and the non-ostensive conditions of the object-choice task. We did not include data for the control condition, as attentiveness was not coded for the control condition. We fitted a Beta Regression Model (R package glmmTMB version 1.1.7 (Brooks et al., 2017)), setting the family argument to “ordbeta”, in order to be able to use the true bounds of the dependent variable [0,1] (Kubinec, 2022). The main independent variable of interest was the interaction between condition (ostensive or non-ostensive) and pig group (companion pigs, lab pigs or commercial pigs). We additionally included and thereby controlled for trial number (1–6, within condition, z-transformed), condition order (whether the condition was first or second, z-transformed) and sex of the pig as fixed effects. Trial number and condition were included as random slopes within the random intercept of subject. For this purpose, condition was dummy-coded.

Collinearity was not an issue as the highest variable inflation factor (VIF) was at 1.633. The model was based on 636 observations across 54 pigs.

To test the effect of the interaction between pig group and condition on pigs’ success in finding the baited bowl in the object choice task, we fitted a Generalized Linear Mixed Effects Model (R package lme4 version 1.1-33 (Bates et al., 2015)) with a binomial distribution. We controlled for trial number (1–6, within condition, z-transformed), condition order (1-3, z-transformed), the side on which the food was hidden (left or right) and the pig’s sex. The pigs’ relative attentiveness could not be included as a fixed effect, given that attentiveness was not coded in the control condition. In addition, we opted for including condition order, even though this moderately increased collinearity (see below) due to the fact that the control condition always came third. Subject was considered as a random intercept with the random slopes of condition (dummy-coded) and trial number. The correlations between the random slopes and random intercept were removed as they were close to 1 or -1 (Matuschek et al., 2017).

The full model was not overdispersed (dispersion ratio = 1.019) and collinearity was moderate with the highest VIF being at 4.609. The model was based on 904 observations across 54 pigs.

4.8.2 Analysis A-not-B Task

To analyze the effect of the interaction between condition and pig group on the pigs’ attentiveness during the demonstration of the A-not-B task, we fitted a Beta regression model (R package glmmTMB version 1.1.7 (Brooks et al., 2017)). We controlled for trial (A1, A2, B1, B2, A3), session number (1 or 2, z-transformed), the pig’s sex, the pig’s A side (left or right), the set-up (screens or cardboard), and the number of unsuccessful A trials ("warm-up trials") conducted before the two consecutive successful A trials (A1 and A2). The random slope of condition (dummy-coded) was included within the random intercept of subject.

No collinearity was detected (all VIFs < 1.825). The model was based on 498 observations across 50 subjects.

To analyze pigs' success in the A-not-B task, we only considered trials B1, B2 and A3, as trials A1 and A2 were per definition successful (they were repeated until the pig chose correctly in two consecutive trials). We fitted a Generalized Linear Mixed Effects Model (R package lme4 version 1.1-33 (Bates et al., 2015)) with a binomial distribution. The main fixed effects of interests were condition, pig group and trial (B1, B2 or A3) as well as all possible interactions between the three. We controlled for condition order (1 or 2, z-transformed), the pig's A side, the pig's sex, the relative attentiveness and the set-up (cardboard or screens) as well as the number of unsuccessful A trials ("warm-up trials"). We included subject as a random effect with the random slopes of condition and set-up.

The full model was not overdispersed (dispersion ratio = 1.074) and collinearity was moderate (highest VIF = 3.848). The model was based on 297 observations across 50 pigs.

To assess whether pigs performed significantly above or below chance level in trials B1, B2 and A3, we checked the 95-% confidence intervals for each combination of trial, condition and group and considered the deviation significant whenever an interval did not overlap with 0.5 (chance level).

4.8.3 Analysis Detour Task

We fitted a Beta regression Model similar to the ones described for the object-choice and A-not-B tasks to analyze the effect of the interaction between condition and pig group on pigs' attentiveness in the demonstration trials (trials 4 to 6) of the detour task. Additionally, session number, trial number (only demonstration trials 4–6, within condition), set-up (J or mirror-image J) and the pig's sex were controlled for. We added condition (dummy-coded) and set-up (dummy-coded) as random slopes for the random intercept of subject.

The fixed effects were found to not be collinear (all VIFs < 1.657). The model was based on 298 observations across 50 subjects.

To analyze the latency to reach the target in the demonstration trials of the detour task, we conducted a survival analysis using the Cox Mixed Effects Model (R package coxme version 2.2.18.1 (Therneau, 2020)). The response variable for such models is a combination of the time until the event occurs (in our case success, see Table 3) as well as the fact whether the event occurred (0/1). We investigated the effect of the fixed effects condition, pig group and trial number (within the demonstration trials of each condition, i.e., 4–6) as well as all possible interactions between these effects. In addition, we considered condition order, set-up (J or mirror-image-J), the relative attentiveness, the pig's sex and the average latency in the three no-demonstration trials of the given session as control variables in the model.

Collinearity between fixed effects was moderate (highest VIF = 3.500). The model was based on 298 observations across 50 subjects.

To find out whether the human demonstrations were successful in general, regardless of the condition, we fitted another Cox Mixed Effects Model (R package coxme version 2.2.18.1 (Therneau, 2020)) investigating the effect of the interaction between trial type (no-demonstration or demonstration), session number and pig group on the latency to reach the target, while controlling for trial number (within session, 1–6), set-up (J or mirror-image J) and the pig's sex.

Collinearity between fixed effects was not an issue (highest VIF = 1.784). The model was based on 598 observations across 50 subjects.

4.8.4 Sample Size, Excluded Trials and Subjects

A total of 54 pigs passed the warm-up phase of the object-choice task and participated in the test. Out of 972 planned trials, 902 valid trials were included in the analysis. 63 control trials, one ostensive trial and six non-ostensive trials were not conducted due to the pigs' lack of motivation.

In the A-not-B task, one lab pig did not participate due to lameness, one commercial pig could not be motivated to complete the test and two more commercial pigs only completed one A-not-B test session, in one case due to a lack of food motivation and in another case due to experimenter error leading to the same condition being presented in both sessions. This left us with a sample size of 50 pigs. Out of 500 planned trials (5 trials in each of two conditions for each of 50 pigs), 498 were conducted and were included in the analysis investigating attentiveness. In one A3 trial, attentiveness could not be coded due to equipment failure and another one was erroneously omitted. When analyzing pigs' success, we only considered trials B1, B2 and A3 (see below), which comprised 297 out of 300 planned trials. In addition to the trial that was omitted, in two trials, the pig failed to choose even when we repeated this trial.

The sample size for the detour task amounted to 50 pigs. One companion pig showed fear of the fence and was therefore excluded, one lab pig did not participate due to lameness, one commercial pig lacked food motivation and another commercial pig erroneously experienced the same condition twice and was therefore excluded from the analysis. Out of 300 planned demonstration trials, 298 were included in the analyses of attentiveness and latency. One trial was omitted due to experimenter error and another trial was excluded because the pig managed to obtain the food by lifting the fence over the bowl rather than by detouring the fence.

5. Results

5.1 Object-Choice Task: Attentiveness

The full-null model comparison revealed a significant effect of condition and pig group, or the interaction between the two, on the pigs' attentiveness in the object-choice task ($\chi^2_5 = 56.84$, $p < 0.001$, see Table A2 for full model output). The two-way interaction itself was not significant ($\chi^2_2 = 0.22$, $p = 0.89$), but the single term of group was ($\chi^2_2 = 54.31$, $p < 0.001$). There was a tendency for condition to significantly modulate pigs' attentiveness ($\chi^2_1 = 605.22$, $p = 0.085$), see Figure 7. Pairwise comparisons of the pig groups revealed that commercial pigs were significantly less attentive than companion ($z = -6.549$, $p < 0.001$) and lab pigs ($z = -9.273$, $p < 0.001$), but the difference between companion and lab pigs was not significant ($z = -0.695$, $p = 0.767$).

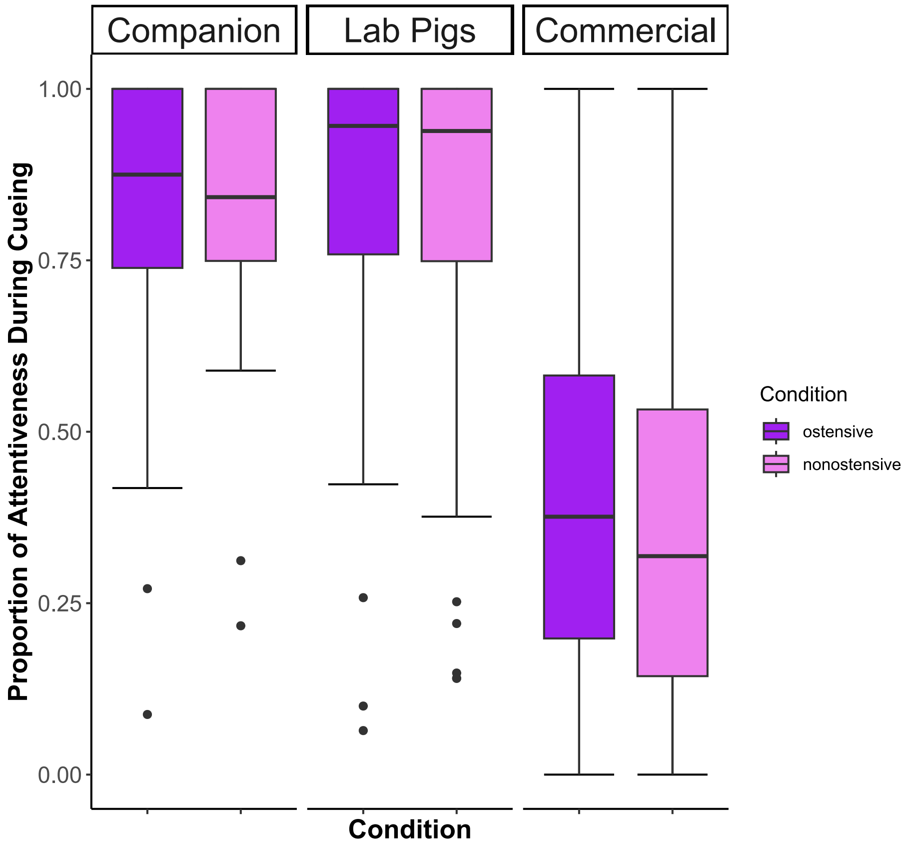

Figure 7: Proportion of cueing the pigs paid attention to in the object-choice task for the three pig groups in the two conditions (ostensive in purple, non-ostensive in pink).

5.2 Object-Choice Task: Success

Overall, pigs successfully followed the experimenter's directional cues in 51% of the trials. The main effects condition and pig group, or their interaction, did not significantly influence pigs' success in following the experimenter's directional cues in the object-choice task (full-null model comparison:, $\chi^2_8 = 5.51$, $p = 0.70$, see Figure 8, for full model output see Table A3).

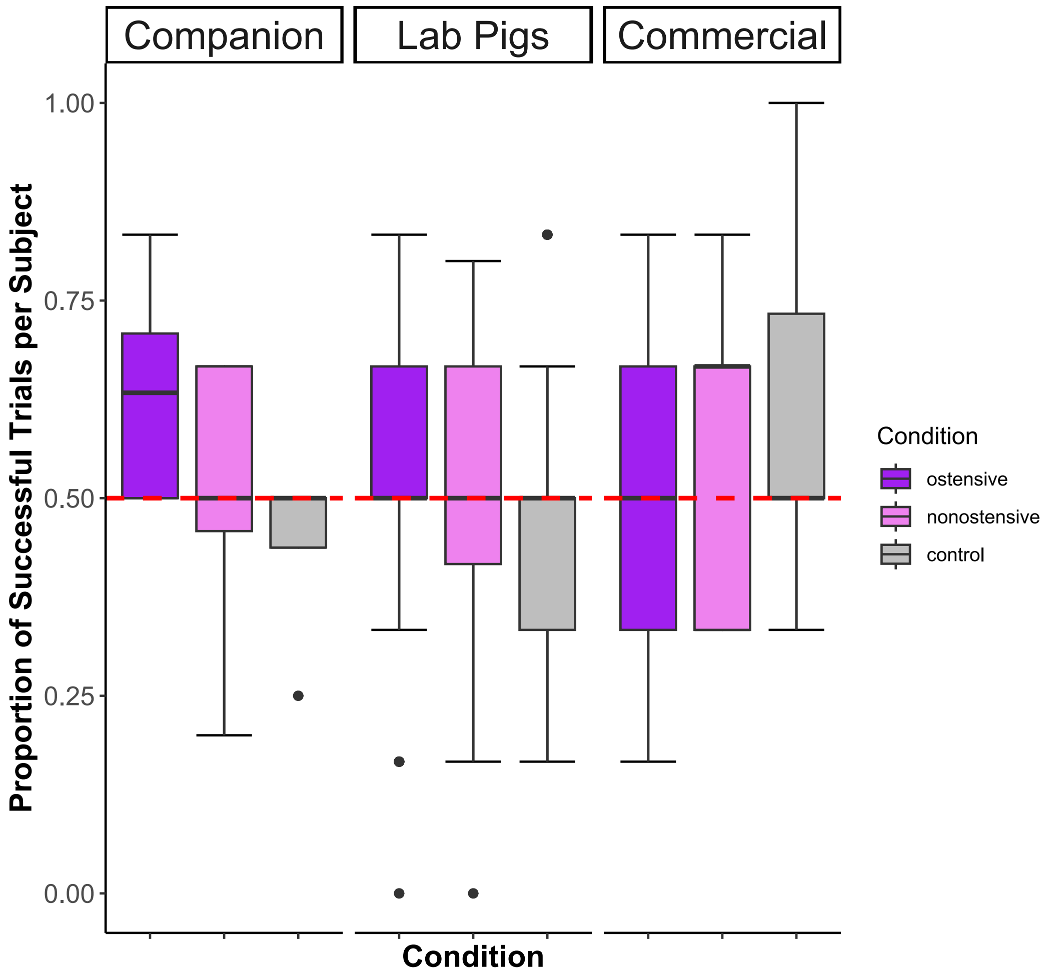

Figure 8: Proportion of successful trials per subject in the object-choice task for the three pig groups and three conditions (ostensive in purple, non-ostensive in pink and control in gray).

5.3 A-not-B Task: Attentiveness

The full-null model comparison for the pigs' attentiveness in the A-not-B test revealed a significant effect of either the fixed effects condition and pig group or their interaction ($\chi^2_5 = 126.57$, $p < 0.001$, for full model output see Table A4). While neither the two-way interaction ($\chi^2_2 = 0.552$, $p = 0.76$), nor the single term condition ($\chi^2_1 = 0.572$, $p = 0.45$) was significant, the single term group had a significant effect on the pigs' attentiveness ($\chi^2_2 = 56.519$, $p < 0.001$, see Figure 9). Pairwise comparisons revealed that commercial pigs' attentiveness was significantly lower than that of companion ($z = -6.111$, $p < 0.001$) and lab pigs ($z = -10.067$, $p < 0.001$). Lab pigs also tended to be more attentive than companion pigs ($z = -2.226$, $p = 0.067$).

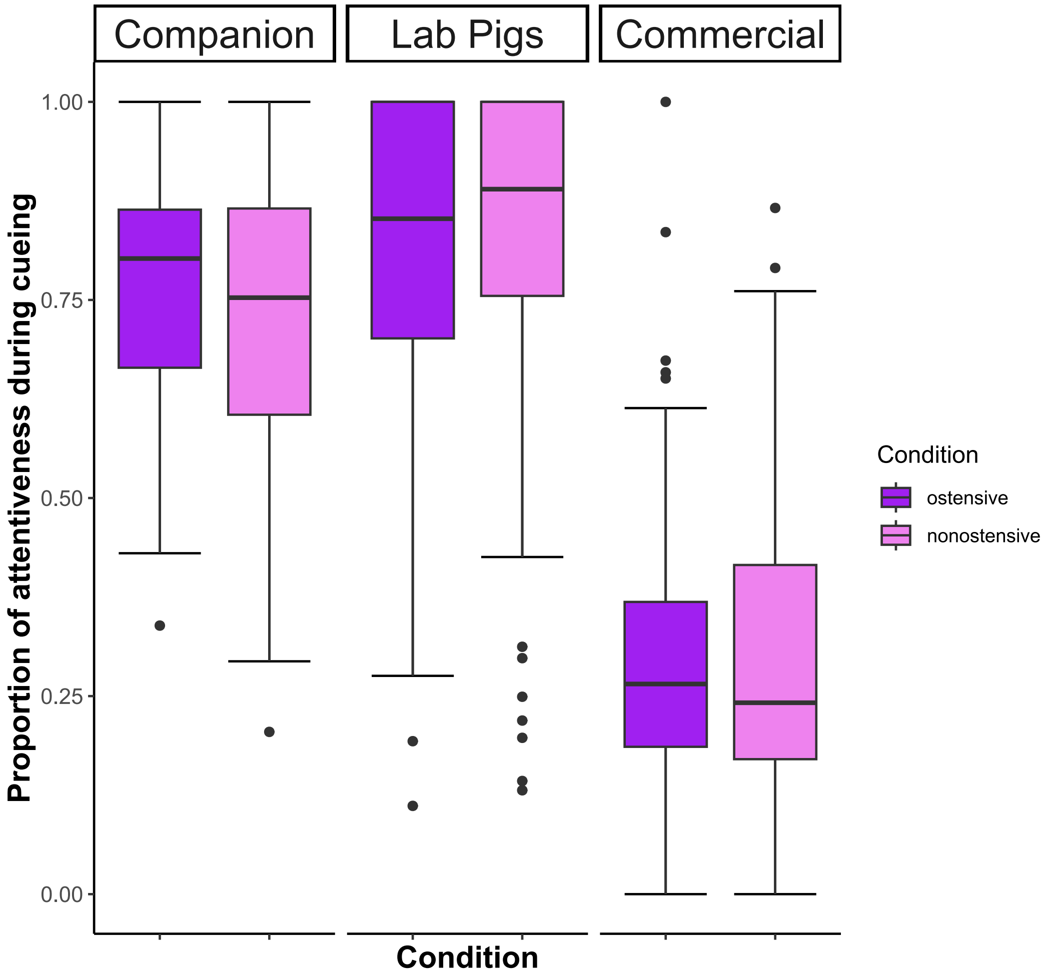

Figure 9: Proportion of cueing the pigs were attentive to in the A-not-B task for the three pig groups and two conditions (ostensive in purple and non-ostensive in pink).

5.4 A-not-B Task: Success and A-not-B Error

The full-null model comparison for the pigs' success in the A-not-B task revealed a significant effect of either the main fixed effects condition, pig group and trial (B1, B2, A3), or their possible interactions ($\chi^2_{11} = 40.51$, $p < 0.001$, for full model output see Table A5). The three-way interaction was not significant ($\chi^2_4 = 1.827$, $p = 0.76$) and neither were any of the two-way interactions (condition and pig group: $\chi^2_2 = 2.497$, $p = 0.238$ condition and trial: $\chi^2_2 = 1.803$, $p = 0.41$; pig group and trial: $\chi^2_4 = 3.970$, $p = 0.41$). Only the single terms pig group ($\chi^2_2 = 10.675$, $p = 0.004$) and trial ($\chi^2_2 = 328.269$, $p < 0.001$) had a significant effect on pigs' success, while condition did not ($\chi^2_1 = 0.153$, $p = 0.696$) (Figure 10). Looking at the 95%-confidence intervals, those for lab pigs' B1 trials in both conditions were below 0.5, meaning that they performed significantly below chance level and companion pigs performed significantly above chance level in the non-ostensive A3 trials (see Table 4). All eight companion pigs were successful in their ostensive A3 trial.

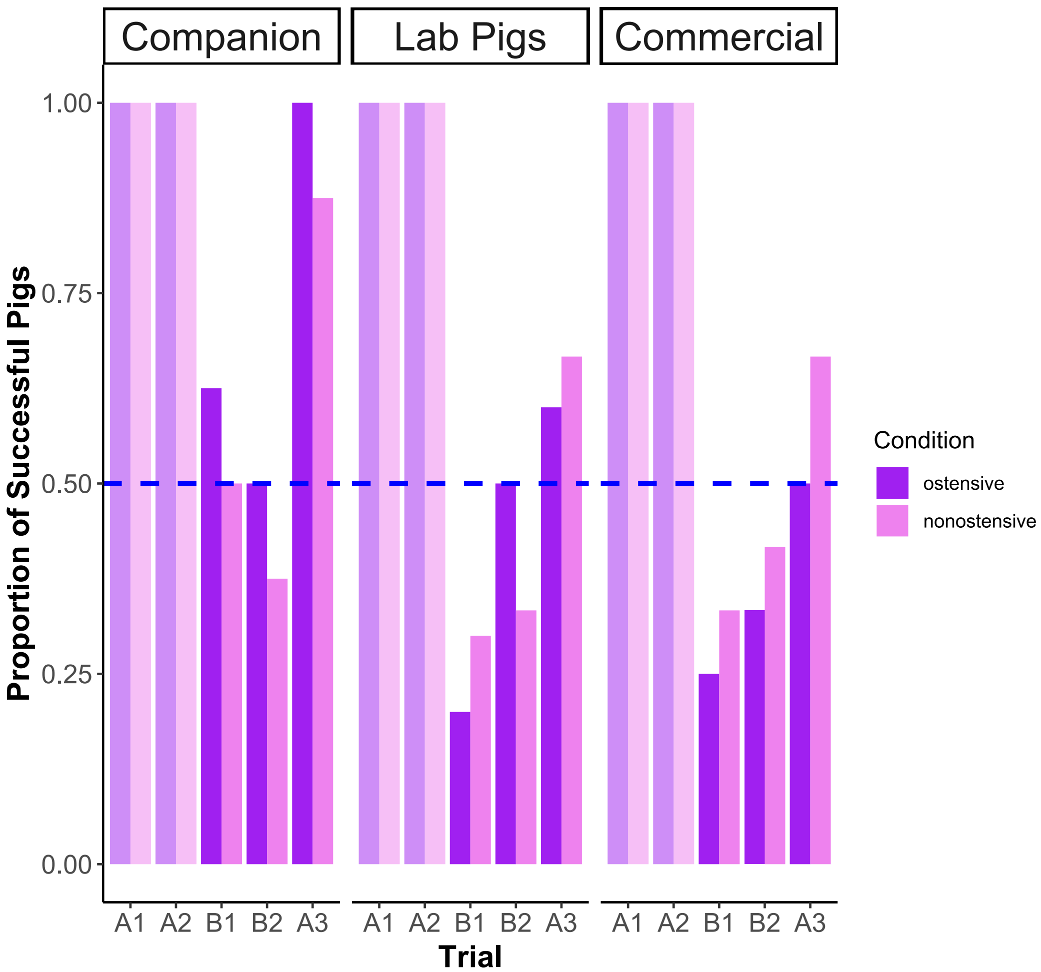

Figure 10: Proportion of successful pigs per trial, condition (ostensive in purple and non-ostensive in pink) and pig group. The dashed blue line indicates chance level (0.5). Trials A1 and A2 were per definition successful.

Table 4: 95%-confidence intervals of pigs' estimated success rate for each combination of condition, pig group and trial in the A-not-B task. Trials in which pigs performed significantly above or below chance level (CIs do not overlap with 0.5) are printed in bold face.

Pig Group	Condition	Trial	Estimated Probability of Success	Lower 95%-CI	Upper 95%-CI
Commercial	Ostensive	B1	0.23	0.07	0.54
Commercial	Ostensive	B2	0.32	0.12	0.62
Commercial	Ostensive	A3	0.48	0.22	0.76
Commercial	Non-ostensive	B1	0.33	0.12	0.63
Commercial	Non-ostensive	B2	0.41	0.17	0.70
Commercial	Non-ostensive	A3	0.67	0.36	0.87
Companion	Ostensive	B1	0.72	0.34	0.93
Companion	Ostensive	B2	0.59	0.19	0.90
Companion	Ostensive	A3	> 0.99	0.00	1.00
Companion	Non-ostensive	B1	0.54	0.22	0.83
Companion	Non-ostensive	B2	0.41	0.14	0.75
Companion	Non-ostensive	A3	0.67	**0.51**	**0.99**
Lab Pigs	Ostensive	B1	0.18	**0.08**	**0.35**
Lab Pigs	Ostensive	B2	0.48	0.30	0.65
Lab Pigs	Ostensive	A3	0.58	0.40	0.74
Lab Pigs	Non-ostensive	B1	0.30	**0.17**	**0.49**
Lab Pigs	Non-ostensive	B2	0.34	0.19	0.53
Lab Pigs	Non-ostensive	A3	0.68	0.50	0.82

5.5 Detour Task: Attentiveness

In the analysis targeting pigs' attentiveness in the demonstration trials of the detour task, the full-null model comparison revealed a significant effect of condition, pig group, or the interaction between the two ($\chi^2_5 = 67.00$, $p < 0.001$, see Figure 11, for full model output see Table A6). The two-way interaction was not significant ($\chi^2_2 = 0.650$, $p = 0.72$), but pigs were significantly more attentive in the ostensive than in the non-ostensive condition ($\chi^2_1 = 5.165$, p = 0.02) and the pig groups differed significantly (χ^2_2 = 61.315, p < 0.001). When conducting pairwise comparisons between the pig groups, we detected significant differences for all pairs (commercial and companion pigs: z = -5.720, p < 0.001; commercial and lab pigs: z = -10.385, p < 0.001; companion and lab pigs: z = -3.084, p = 0.006).

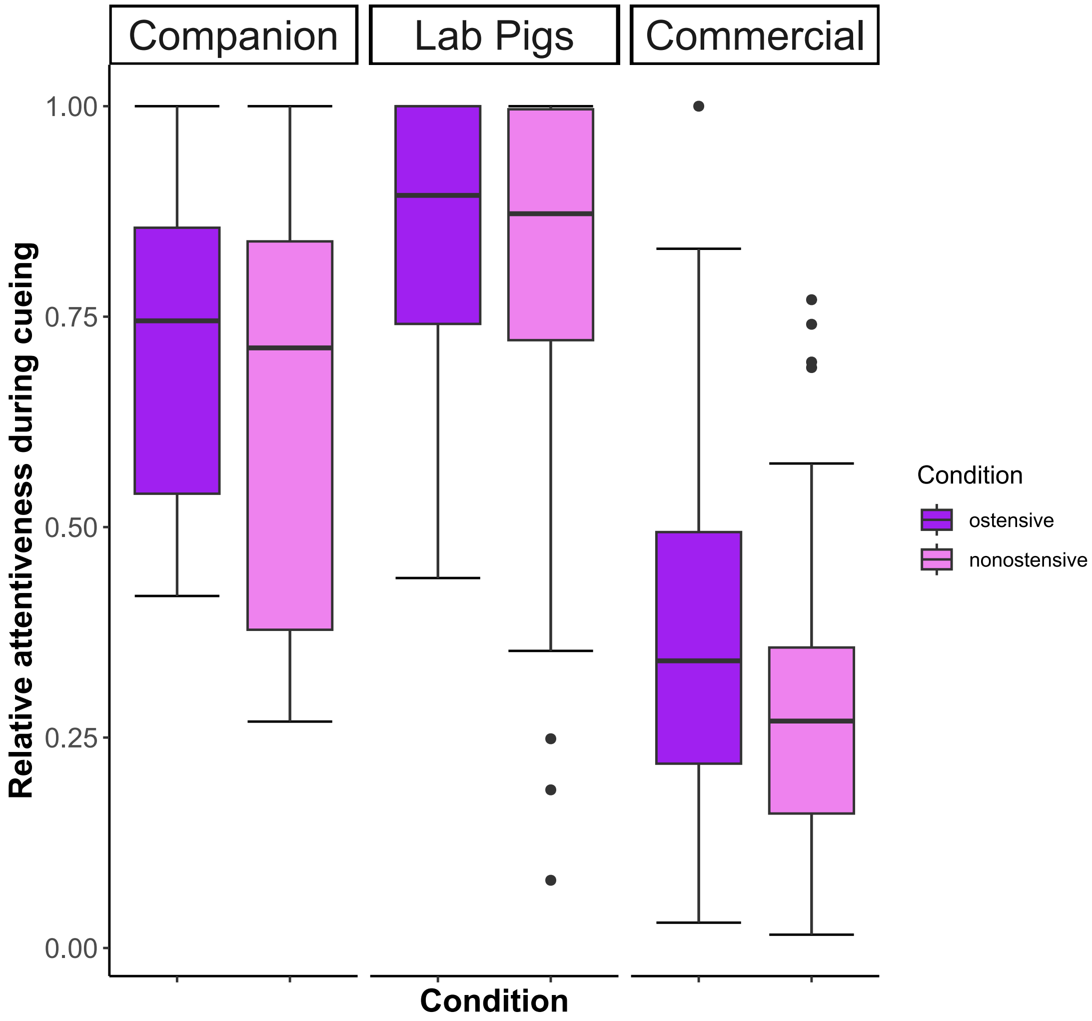

Figure 11: Relative attentiveness during the experimenter's demonstration in the demonstration trials of the detour task for the three pig groups and two conditions (ostensive in purple and non-ostensive in pink).

5.6 Detour Task: Success and Latency

The full-null model comparison revealed a significant effect of the fixed effects condition, pig group, trial number, or any of their interactions, on pigs' latency to reach the target (χ^2_{11} = 42.19, p < 0.001, for full model output see Table A7). The three-way interaction did not have a significant effect (χ^2_2 = 0.79, p = 0.67), and none of the two-way interactions was significant either (condition and pig group: $\chi^2_2 = 0.40$, $p = 0.82$; condition and trial number: $\chi^2_1 = 0.62$, $p = 0.43$; pig group and trial number: $\chi^2_2 = 0.26$, $p = 0.88$). The single factors pig group ($\chi^2_2 = 33.22$, $p < 0.001$) and trial number ($\chi^2_1 = 8.78$, $p < 0.001$) had a significant influence, but condition did not ($\chi^2_1 = 0.01$, $p = 0.94$), see Figure 12. Pairwise comparisons of the pig groups revealed that lab pigs' latencies differed significantly from those of commercial ($z = -4.937$, $p < 0.001$) and companion ($z = -3.305$, $p = 0.0027$) pigs, but commercial and companion pigs' latencies did not differ significantly ($z = -2.033$, $p = 0.10$).

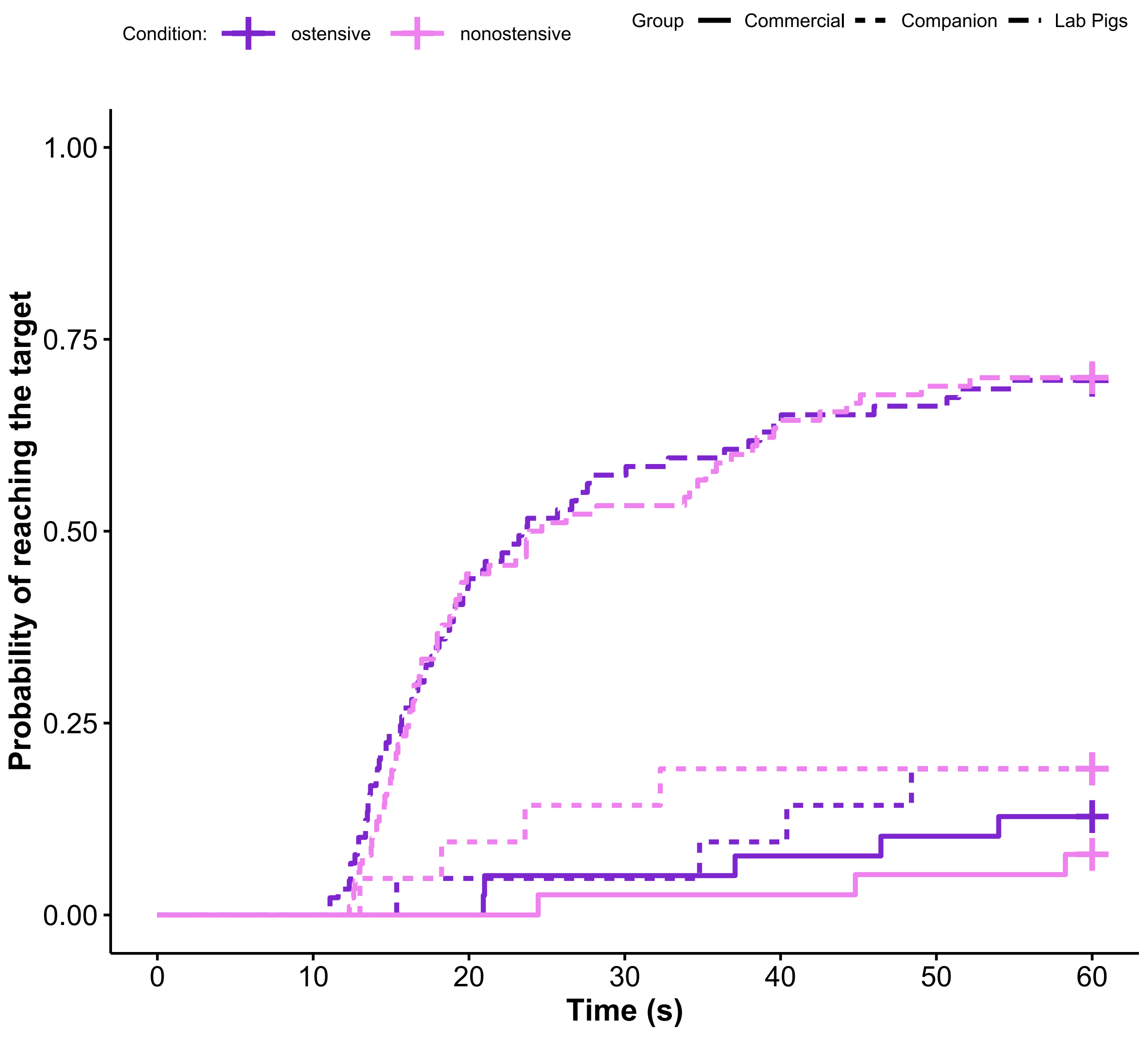

Figure 12: Probability of reaching the target across time (max. 60 s, i.e., the length of a trial) for the three pig groups (Commercial = solid line, Companion = short-dashed line, Lab Pigs = long-dashed line) and two conditions (ostensive in purple and non-ostensive in pink). Crosses at the end indicate censored datapoints, i.e., trials in which the pig did not reach the target within 60 s.

The research pigs were clearly more successful in this task than the other two groups: Three out of seven companion pigs, seven out of 13 commercial pigs and all 30 lab pigs solved the detour task within 60 s in at least one of their 12 trials. With the following analysis we investigated to what extent they benefited from the demonstrations and how successful they were even in the no-demonstration trials.

To see whether the above lack of significant difference between conditions was due to the ineffectiveness of the human demonstrations in general or whether the demonstration was equally effective in both conditions, we compared pigs' latencies between the demonstration and no-demonstration trials. The full-null model comparison revealed a significant effect of the fixed effects trial type (demo or no-demo), session number and group, or any interaction between the three ($\chi^2_2 = 213.93$, $p < 0.001$; see Figure 13). The three-way interaction itself did not have a significant effect ($\chi^2_2 = 0.065$, $p = 0.97$). Among the two-way interactions, only that between trial type and pig group was significant ($\chi^2_2 = 7.111$, $p = 0.03$), but not those between trial type and session number ($\chi^2_1 < 0.001$, $p = 0.989$) and between pig group and session number ($\chi^2_2 = 1.295$, $p = 0.52$). For pairwise comparisons see Table 5.

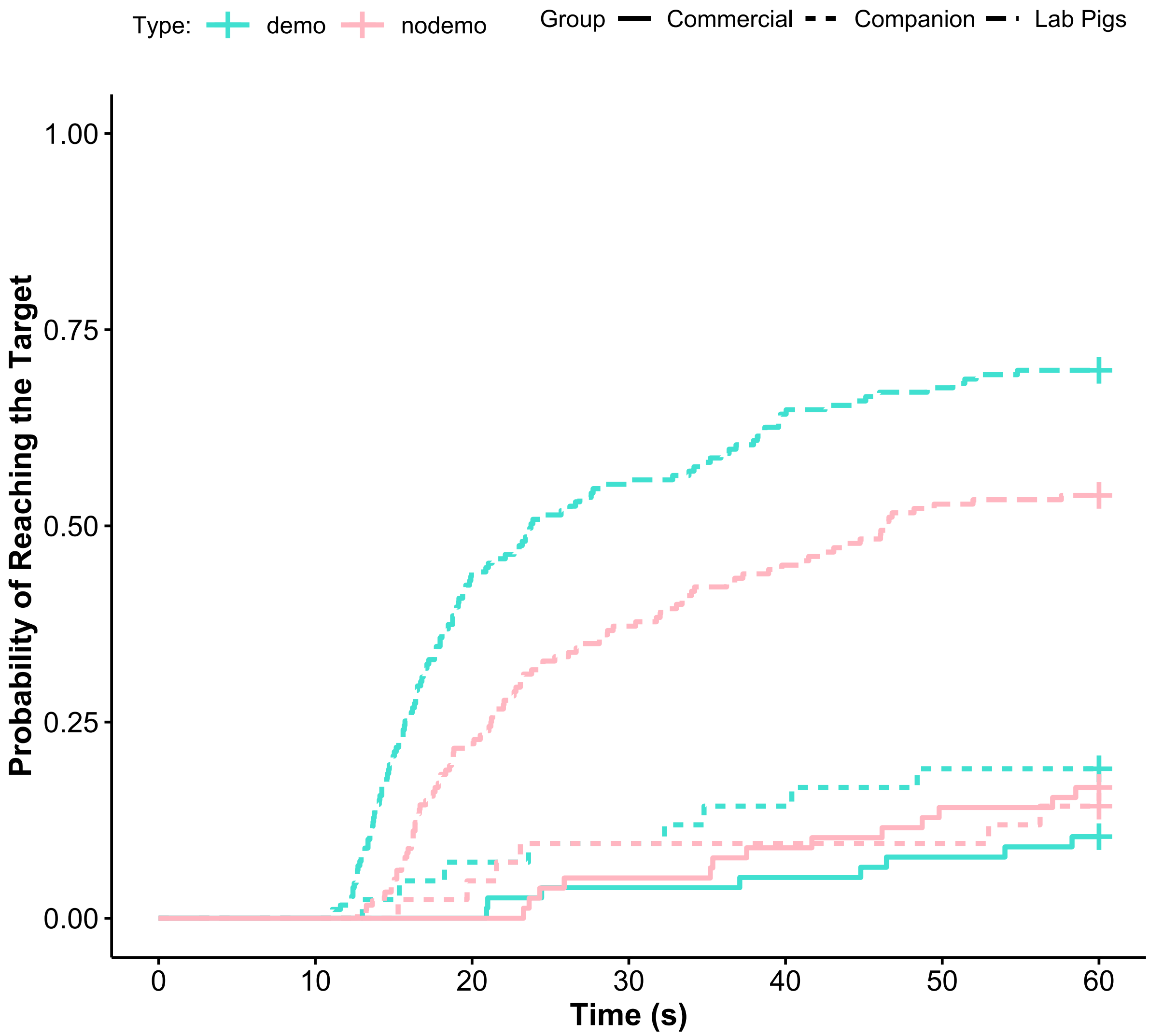

Figure 13: Probability of reaching the target across time (max. 60 s, i.e., the length of a trial) in no-demonstration (light pink) and demonstration (turquoise) trials of the detour task for the three pig groups (Commercial = solid line, Companion = short-dashed line, Lab Pigs = long-dashed line).

Table 5: Results of pairwise comparisons of pigs' latencies for the relevant combinations of pig group and trial type. Significant p-values are printed in bold face.

Pig group and trial type 1	Pig group and trial type 2	z	p-value	Estimate	Standard Error
Commercial - demo	Commercial - nodemo	-0.874	0.960	-0.458	0.524
Companion - demo	Companion - nodemo	0.269	0.999	0.206	0.765
Lab Pigs - demo	Lab Pigs - nodemo	4.635	**< 0.0001**	0.725	0.156
Commercial - nodemo	Companion - nodemo	0.432	0.990	0.278	0.644
Commercial - nodemo	Lab Pigs - nodemo	-4.292	**0.0003**	-1.535	0.358
Companion - nodemo	Lab Pigs – nodemo	-3.230	**0.007**	-1.814	0.561

5.7 Length of Cueing/Demonstrations

The cueing duration in the non-ostensive condition was significantly longer than in the ostensive condition for both the object-choice ($W = 77367$, $p < 0.001$; $mean_{ostensive} = 4.12$ s, $mean_{non-ostensive} = 4.64$ s) and the A-not-B task ($W = 60209$, $p < 0.001$; $mean_{ostensive} = 8.39$ s, $mean_{non-ostensive} = 10.56$ s). Also the non-ostensive detour demonstration was significantly longer than the ostensive one ($W = 3526$, $p < 0.001$; $mean_{ostensive} = 12.35$ s, $mean_{non-ostensive} = 13.81$ s). These differences are visualized in Figure 14.

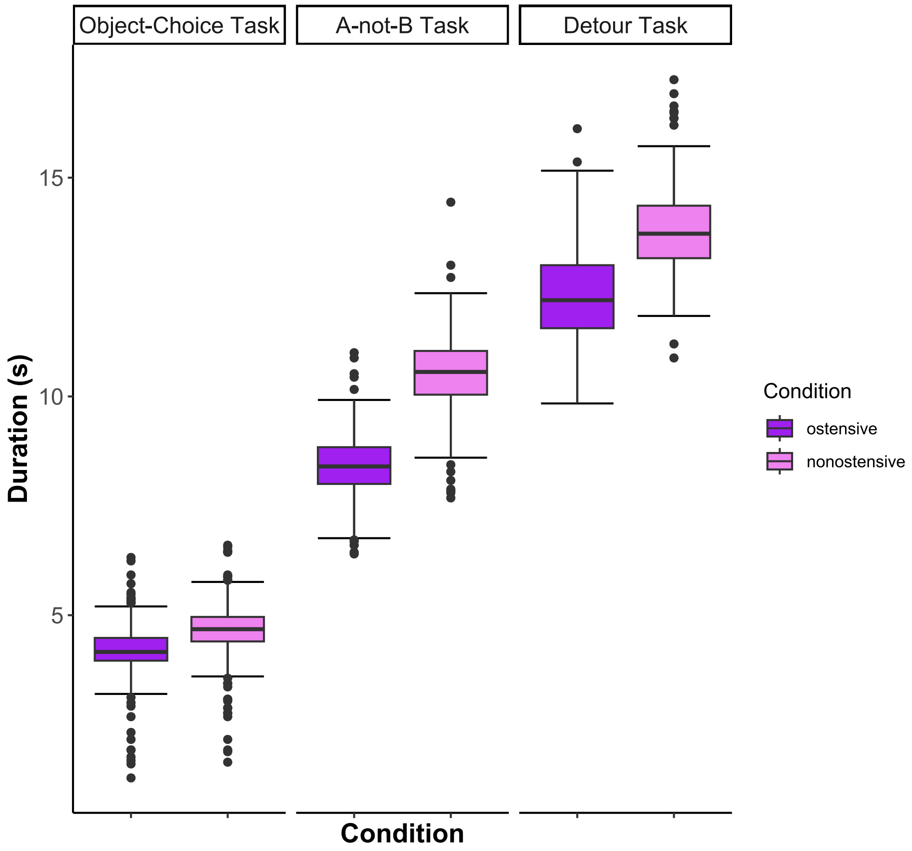

Figure 14: Duration (in seconds) of the cueing or the demonstration in the ostensive (purple) and non-ostensive (pink) conditions of the object-choice, A-not-B and detour tasks. Note that some cueing durations in the object-choice task were particularly short because most companion pigs were not restrained during cueing in this task and sometimes made a choice before the experimenter had presented all three directional cues.

6. Discussion

In the present study, we investigated sensitivity to human ostensive communication in three groups of pigs differing in their experience with human communication. We found that pigs, independently of their experiences, were more attentive to ostensive than non-ostensive human detour demonstrations and their attentiveness in an object-choice task with directional cues showed a similar tendency. However, neither their attentiveness in an A-not-B task nor their attentiveness-independent learning in any of the tasks were enhanced by ostension. More precisely, pigs struggled to follow directional gaze and body orientation cues independently of ostension, committed the A-not-B error in both conditions and were able to learn from both ostensive and non-ostensive human detour demonstrations. Even though the pig groups did not differ in their sensitivity to ostension, they did differ in their attentiveness to human demonstrations and also in their success with two out of the three tasks. That is, lab pigs were generally most and commercial pigs least attentive to human demonstrations. Noteworthily, companion pigs' attentiveness was intermediate between commercial and lab pigs'. In addition, lab pigs performed best in the detour task and were most likely to commit the A-not-B error.

6.1 Attentiveness

Unlike for dogs (e.g., Kaminski et al., 2012; Pongrácz et al., 2004; Topál et al., 2009), horses (Lansade et al., 2021) and human infants (e.g., Topál et al., 2009), ostension did not impact pigs' learning in the three tasks, but it did increase their attentiveness in some cases. Interestingly, in our study, the effect of ostension on pigs' attentiveness only reached statistical significance for the detour task. One reason for this could be that the detour task was the most challenging task. The difficulties pigs faced in the no-demonstration trials that preceded the demonstration trials in both conditions could have made pigs more receptive to potentially helpful ostensive human demonstrations. In contrast, in the A-not-B task, pigs were also allowed to retrieve the food if they chose incorrectly. Therefore, the only costs of not watching the demonstration closely enough were the negligible extra effort and time it takes to check the incorrect screen first. Alternatively, one could argue that, in the detour task, the demonstration was longer than the cueing in the object-choice and A-not-B tasks (on average 13.08 s), which could have created more room for variation between conditions. Similarly, the longer duration of the demonstration could have counter-acted the ceiling effect in lab pigs, which potentially masked any effects of ostension on attentiveness in the A-not-B task.

However, we cannot rule out that what caused the difference in pigs' attentiveness between conditions in the detour task is the difference in the length of the demonstration. That is, the duration of the demonstration was slightly but significantly shorter in the ostensive condition than in the non-ostensive condition. The reason for this is presumably that, in the non-ostensive condition, an entire sentence ("Where could I hide the food?") was uttered rather than a short command or name. Even though we calculated and analyzed pigs' attentiveness relative to the duration of the demonstration, pigs might have nevertheless paid proportionally more attention to shorter demonstrations, while they more easily got distracted during longer ones. What weakens this interpretation, however, is the fact that the difference in demonstration duration between conditions was most pronounced in the A-not-B task (mean difference = 2.17 s), for which pigs' attentiveness was not significantly influenced by condition. In contrast, the mean differences in duration between conditions were smaller for the object-choice task (0.52 s) and the detour task (1.46 s), for which pigs' attentiveness was tendentially or significantly higher in the ostensive condition. Similarly, the subtle difference in cueing/demonstration length between conditions can be assumed to have affected the commercial pigs, who were least attentive, the least. Despite this, they too paid more attention to ostensive demonstrations. Consequently, our findings still suggest that the way *how* the demonstration was performed (ostensive or non-ostensive), rather than its length, affected the pigs' attentiveness.

In addition to these remarkable effects of ostension on the attentiveness of all pigs, we also detected considerable ostension-independent group differences in pigs' attentiveness. That is, commercial pigs were generally less attentive than companion and lab pigs, with the latter being most attentive in all tasks. This raises the intriguing question of what the reasons for these differences might be.

First, lab pigs might have been most and commercial pigs least attentive due to the age difference between groups. While lab pigs were between seven and ten years old at the time of testing, the oldest commercial pig was only three years old, due to the artificially shortened lifespan of commercial breeding sows. A recent study on horses found that older horses were more successful at following human-given cues (Liehrmann et al., 2023). Even though attentiveness was not explicitly measured, the authors discuss that older horses might be more attentive and less distracted than their younger peers. In addition, pigs' inhibitory control has been shown to improve with age (Krause et al., 2021) in a study comparing 9- and 16-week-old individuals. This suggests that the results obtained for horses might be transferable to pigs and that their older age allowed the lab pigs to be more attentive and less distracted in our study.

Independently of age, training experience can be considered a second important driver of the observed group differences. The commercial pigs, which were the least attentive group in all tasks, are the only group that did not have any previous testing or training experience. In a similar vein, Veit et al. (2023) suggest that the reason pigs were most attentive to a human demonstration (as opposed to a conspecific and a ghost demonstration) in a social learning study could be their training experience or their learned association between food and humans. Contrary to the lab pigs that participated in our and Veit et al.'s study as well as the companion pigs, the commercial pigs in our sample seldom receive food directly from humans, as they are fed via automatic feeding systems. Therefore, they are unlikely to have formed strong associations between humans and food. This, in turn, might further decrease commercial pigs' motivation to attend to human actions.

Third, we cannot rule out that the low levels of attentiveness in the commercial group might be a coding artefact. This is because, according to the ethogram, a pig was not considered attentive when it visibly manipulated other objects, such as the door of the start box, even if its head was oriented towards the experimenter. Given the flexibility of the fence from which the door was built in the case of the commercial pigs, it is conceivable that commercial pigs' manipulation of the door was more visible, and therefore more likely to be coded, than that of companion and lab pigs. In addition, this flexibility of the fence might have invited manipulation of the door more than the sturdier materials used for the start boxes of the companion and commercial pigs.

Considering all the differences between the pig groups that likely affected their human-directed attentiveness, it is even more remarkable that they all paid more attention to ostensive human demonstrations than to non-ostensive ones. This suggests that either a limited amount of exposure to humans (the amount that commercial pigs experienced in the course of one to three years) is sufficient for pigs to develop such a sensitivity to human ostension or that pigs' sensitivity relies on genetic predispositions that evolved for purposes other than responding to human ostension. Future research will have to confirm pigs' increased attentiveness to ostensive human action and to elucidate the mechanisms that underpin it.

6.2 Learning and Success

In contrast to their attentiveness, we did not find evidence that human ostension affects pigs' attentiveness-independent learning. Note that in our statistical models analyzing the effects of ostension on success we controlled for attentiveness in order to investigate whether ostension enhanced pigs' learning beyond increasing their attentiveness. This pattern of results is similar to that reported for cats which were more attentive to ostensive cues in an object-choice task, even though this increased attention did not lead to an improvement in success (Pongrácz et al., 2019). There are several potential reasons why we failed to detect an effect of ostension on pigs' learning.

First, our results may indeed indicate that pigs, unlike dogs and human infants, do not interpret ostensive human demonstrations differently (as more generalizable or more imperative) than non-ostensive ones. If so, one might conclude that neither domestication (and minimal taming) nor extensive exposure to humans and learning about their communication are sufficient to make animals' learning susceptible to human ostension. Instead, selection for companionship and co-working with humans may be a crucial component that has contributed to dogs' and horses' sensitivity to human ostension. In contrast to these species, the selection of pigs has focused on production traits rather than communication with human caregivers. Such an explanation would be in line with a recent study that found cooperative dog breeds to learn better from human demonstrations in a detour task than independent breeds (Dobos & Pongrácz, 2023). However, this protocol only comprised ostensive demonstrations. Nevertheless, in combination with the fact that ostensive demonstrations were more effective for dogs than non-ostensive ones in an earlier study (Pongrácz et al., 2004), one could cautiously speculate that breeds and, more generally, species selected for working tasks could also be more sensitive to ostension. During their domestication history, it might have been less relevant for pigs to learn selectively from ostensive human demonstrations. Rather, adjusting to human behavior in general, regardless of whether the animals are addressed or not, might have helped pigs to obtain food and to cope with human proximity.

A second reason could be that the tasks we employed were simply not suitable for detecting an effect of human ostension on pigs' learning. For example, detouring an obstacle might be more ecologically relevant for predator species like dogs than it is for prey species like pigs. However, other prey species, such as equids (McVey et al., 2018; Osthaus et al., 2013; Rørvang et al., 2015) and small ruminants (Nawroth et al., 2016; Raoult et al., 2021), have been shown to succeed in a detour task. In addition, our analyses show that, unlike for horses (Henriksson et al., 2019; Rørvang et al., 2015), our demonstration was effective in reducing pigs' latency, suggesting that the lack of significant difference between conditions can not solely be attributed to a floor effect. Nevertheless, this effect was largely due to the lab pigs in our sample; it was only in this group that the demonstration significantly reduced the detouring latencies in comparison to the no-demonstration trials and that the pigs reached relatively high success rates in both conditions. Given that these pigs had been tested in another detour task before (Nestelberger, 2019), such prior experience may be necessary to make the task accomplishable for pigs.

The pattern of results in the A-not-B task raises doubts about the suitability of the task for investigating the effects of human ostension on pigs' learning. That is, it is questionable whether the experimenter's demonstration is what caused pigs to commit the A-not-B error – in both conditions. Instead of ostension-induced over-generalization (cf. Topál et al., 2008) or obedience (cf. Kaminski et al., 2012), pigs' high persistence could account for their error. The fact that, unlike dogs and human infants (e.g., Topál et al., 2009), pigs perseverated in both conditions is in line with the results from an unsolvable task comparing pigs and dogs. In this study, pigs continued to manipulate and unsuccessfully attempt to solve the task for significantly longer than dogs did (Pérez Fraga et al., 2021). Because of their high persistence, pigs could hence be more prone to perseverating on a previously rewarded location (side A) than other species. This would also explain lab pigs' and commercial pigs' chance level performance in trial A3, after the food had been hidden behind screen B twice.

In addition, pigs' poor visual acuity (Zonderland et al., 2008) might limit their ability to keep track of the bowl in the experimenter's hands and might therefore encourage them even more to resort to alternative strategies. If this were the case, an A-not-B task might seem unsuitable to probe sensitivity to ostension in pigs. However, the lab pigs that participated in our study have already proven capable of discriminating human faces on a touchscreen (Wondrak et al., 2018) as well as to attend to and learn from human demonstrations at a distance of 180 cm (Veit et al., 2023). In combination with our use of a salient and/or blue (which pigs can discriminate well from other colors (Neitz & Jacobs, 1989)) bowl, these results indicate that pigs should be capable of tracking the bowl – at least if sufficiently attentive.

Further, the low costs of approaching the incorrect screen first could explain pigs' A-not-B error. Pigs were allowed to retrieve the food from the correct screen even when they approached the incorrect screen first, which might have led them to adopt a strategy where they always checked one screen before the other one (e.g., first the one that was baited at least twice in the preceding trials), irrespective of what they saw the experimenter do. The costs of choosing incorrectly were further reduced by the relatively small distance (150 cm) between the screens, which is known to potentially cause distraction in subjects with low inhibitory control and increase the ambiguity of the cues, especially in subjects with poor vision (Clark et al., 2019; Krause et al., 2021; Mulcahy & Call, 2009; Mulcahy & Hedge, 2012). However, in the literature discussing two-way choice tasks in dogs and primates, a distance of 150 cm is already considered "distal" (Clark et al., 2019), which weakens the above-stated arguments.

Also the suitability of the object-choice task with directional gaze and body orientation cues might be limited. After all, previously pigs only succeeded in following human directional cues in one study (Nawroth et al., 2014), but in other experiments, conducted with the companion (Gerencsér et al., 2019) and lab pigs (Wondrak et al., unpublished data) in our sample, the pigs performed relatively poorly. Even though the purpose of the warm-up trials in our study was to let the pigs experience that always only one of the two bowls was baited and that they needed to pay attention to the experimenter, the limited number of trials that could be conducted (10-20 trials) in the given time available for testing without exceeding pigs' attention span might have been insufficient. In addition, the use of a barrier between the subject and the experimenter is known to decrease dogs' success in object-choice tasks (Kirchhofer et al., 2012; Udell et al., 2008). Despite this, we felt the need to separate the experimenter from the pig for safety reasons, which might have, however, caused or exacerbated the floor effect preventing us from seeing an effect of ostension on pigs' performance.

Finally, one could argue that we might have seen differences in learning between the ostensive and the non-ostensive conditions if the owner or a familiar person, instead of a relatively unfamiliar experimenter, had given the cues. However, such an explanation is unlikely for several reasons. On the one hand, the familiarity of the experimenter did not impact dogs' (Pongrácz et al., 2004) and horses' (Liehrmann et al., 2023) performance in previous tasks; and commercial pigs from the same population as in our study, for which finding a sufficiently familiar person would have been most difficult, did not show a difference in oxytocin concentration change after contact with a familiar compared with an unfamiliar handler (Lürzel et al., 2020). In addition, all pigs underwent a habituation procedure in which they became familiar with the experimenter. On the other hand, using multiple experimenters has not been shown to increase reproducibility of results (von Kortzfleisch et al., 2022); even if, admittedly, in our study the owner and the experimenter would have differed more fundamentally. Therefore, we do not assume that the choice of a relatively unfamiliar experimenter alone is what caused the lack of significant differences in performance between conditions.

Even though we did not observe an effect of experience with human communication on a potential learning-enhancing effect of human ostension in pigs, we did find significant ostension-independent group differences in success. Precisely, lab pigs were quickest in the detour task, while companion pigs were most successful, i.e., least likely to commit the A-not-B error, in the A-not-B task.

One plausible reason for these differences is that pigs' social and physical environment influenced their performance in the tasks. While the lab pigs live in a rich social and physical environment full of stimulation and have ample space, the commercial pigs experience (limited) social contact in relatively homogenous groups but are restricted in space and are considerably less enriched; and the companion pigs live in enriched human households, albeit without contact to conspecifics (except for one pig). These differences in social and physical enrichment are likely to lead to differences in behavior and cognitive performance (cf. Averós et al., 2010; Nawroth et al., 2019; Puppe et al., 2007). This is backed up by the finding that horses that were provided more space and social contact were more successful at following human cues compared to less enriched conspecifics (Liehrmann et al., 2023), which might be transferable to pigs.

Environmental enrichment could be particularly essential to the lab pigs' detour success (cf. Albiach-Serrano et al., 2012; Clark et al., 2019). More precisely, lab pigs can be expected to have already encountered more obstacles that required them to take a detour than the indoor-housed commercial pigs. Likewise, the lab pigs' social and physical environment presumably demands a high degree of behavioral flexibility, which is also crucial to success in detour tasks (Kabadayi et al., 2018). However, analogous arguments could be made about the companion pig group whose performance was nevertheless significantly lower than that of the lab pigs. Consequently, a combination of lab pigs' environment, experience and age is most likely to explain their outstanding detour success.

In addition to providing enrichment, the training the companion and lab pigs had received might also have lastingly altered their learning in new tests. In a task that required dogs to open a puzzle box, individuals that had previously received general, non-task-specific training were significantly more successful and spent significantly more time interacting with the apparatus than untrained ones (Marshall-Pescini et al., 2008). These results led the authors to conclude that training might enhance dogs' ability to learn new tasks, even those they have not specifically been trained for. Analogously, it is plausible that their previous training and testing experience has boosted the companion and lab pigs' general learning abilities.

Apart from general training experience, lab pigs' outstanding success in the detour task compared with the other groups could be attributed to better inhibitory control. That is, solving a detour task also requires inhibitory control (Kabadayi et al., 2018), which can be expected to increase with age (cf. Krause et al., 2021) and training. Therefore, the lab pigs might possess higher inhibitory control than the younger pigs which allowed them to outperform the other two groups in the detour task.

Moreover, the lab pigs that participated in the present study already took part in a previous detour task with a different, V-shaped set-up (Nestelberger, 2019). Given that these pigs were also shown to remember a two-step problem-solving task after four years (leading experienced pigs to outperform naïve ones), even though they had not been successful in their first attempts (Veit et al., 2023), we cannot exclude that pigs transferred their previous knowledge to the present task. This might also explain why the lab pigs were already significantly faster than companion and commercial pigs in the no-demonstration trials of the detour task.

Based on our observations during data collection, motivation appears to be decisive to pigs' success in the detour task. That is, especially in the case of the companion pigs, a lack of motivation to detour the fence seemed to impede their success. This is illustrated by the individual latency patterns across trials. Many pigs in all three groups failed to solve the task, or had a considerably longer latency, after they had already succeeded relatively quickly in a preceding trial of the same session. Therefore, even pigs that presumably already knew the route around the fence occasionally lost motivation to solve the task. Considering that dogs detoured the fence consistently enough for the researchers to detect differences between conditions (Pongrácz et al., 2004) and that their sensitivity to ostension in an A-not-B task has been attributed to obedience (Kaminski et al., 2012; Topál et al., 2009), obedience could play a crucial role in dogs' and pigs' detour success. Potentially, pigs' baseline motivation to solve the task for food alone is not sufficient to make them take the lengthy detour. However, one could conjecture that especially the lab pigs might feel the need to obey or please the human experimenters by completing the task. For example, in a previous cognitive bias test (Bock, 2019), some individuals from our study population required an unusually high number of training trials to stop going to the unrewarded location, potentially because they perceived the task to consist in the touching of the bowl (Marianne Wondrak, personal communication, 2023). Tentatively one could argue that this presumably high degree of obedience in the lab pigs might have motivated them to solve the detour task more quickly than the other groups. Finally, more distracting features were present in the gardens in which the companion pigs were tested than in the indoor pens in which the commercial pigs were tested and the tarpaulin-covered arena we used for the lab pigs. Taken together, a higher degree of obedience and a less distracting test arena might have increased lab pigs' motivation to solve the detour task.

Turning to pigs' success in the A-not-B task, it is stunning that the most socialized group, the companion pigs, appeared to be least affected by the human demonstration. While human infants and dogs only commit the A-not-B error after ostensive hiding (e.g., Péter et al., 2015; Topál et al., 2009), the pigs in our sample performed at or below chance level in the B trials of both conditions. Noteworthily, companion pigs' drop in performance in the B1 trials was less pronounced than that of commercial and lab pigs. Analogously, their success in trial A3 was visibly higher than that of the other groups. This pattern of results is particularly surprising as potential explanations for companion pigs' high success rates also apply to the other pig groups and/or the other tasks. On the one hand, one could argue that companion pigs relied on olfaction rather than on visual cues by the experimenter to locate the food in all A-not-B trials. However, it is unclear why (a) they should be more adept at utilizing olfaction and/or more prone to do so than the other pig groups and (b) why the use of olfaction did not also increase their success rate in the object-choice task. On the other hand, companion pigs' intensive socialization with humans might allow them to better follow and act on the experimenter's demonstration. Such an interpretation is, however, at odds with the fact that lab pigs might even be more experienced at watching human demonstrations (due to their participation in numerous studies such as Veit et al., 2023) as well as with companion pigs' poor performance in the object-choice and detour tasks. Alternatively, we cannot rule out that companion pigs' higher success rate in the A-not-B task, which seemingly caused the significant effect of group, can be attributed to stochastic processes and the very limited sample size in this group.

Taken together, the lack of effects of human ostension on pigs' learning in the present study highlights the need for testing other domesticated animals not selected for companionship and for applying modified test batteries to pigs. This would help elucidate whether our null findings stem from methodological shortcomings or truly reflect pigs' capacities – and potentially those of other domesticated non-companion animals. Even more interestingly, the ostension-independent group differences in success that became apparent in our study emphasize the role of enrichment and individual (training) experience on animals' cognitive performance.

6.3 Limitations and Recommendations for Future Studies

Our results and observations made during data collection allow us to identify shortcomings of our current set-up and to formulate recommendations for future studies. Importantly, when interpreting our results, we have to acknowledge many confounding differences between the three pig groups. Apart from the difference that interests us, namely experience with human communication, the groups were also highly unequal in age, testing experience, social and physical environment, body size, season in which they were tested, sex ratio, neutering status and many other regards. On the one hand, counterfactual group differences in sensitivity to ostension would have hence had to be interpreted with caution and the meaningfulness of the ostension-independent group differences we found is limited. On the other hand, the heterogeneity of our sample also increases the external validity of our findings (Bodden et al., 2019; Würbel & Garner, 2007). For example, the effect of ostension on attentiveness in the detour task was independent of group (the interaction between the two effects was not statistically significant), indicating that it might be robust and universal in pigs. However, it would be desirable for future studies to aim for equal and sufficiently large sample sizes, as especially the low number of companion pigs in our sample limits the strength of the conclusions we can draw about highly socialized pigs.

A potential issue that might have decreased pigs' motivation to solve the tasks is that they were also rewarded for going back to the start box after each trial. In fact, especially for the commercial and companion groups, bringing pigs back to the start box was often more effortful and time-consuming than the trials themselves. This is also the reason why it was impossible to use a less preferred reward to lure pigs back to the start box than the one with which the bowls were baited, as many individuals would not have come back to the start box for reward types other than their preferred one. Ideally, subjects should receive extensive training with the start box before tests are conducted to overcome this issue.

Further, a shorter detour could be used to potentially avoid the floor effect that we saw in the commercial and companion pig group. That is, pigs might be more motivated to walk around a shorter detour and would hence be more likely to solve the task, thereby producing a meaningful latency, if they already know the route. This, in turn, would allow researchers to disentangle a lack of understanding from a lack of motivation.

Another aspect worth considering in future studies is to what extent ostensive communication can be standardized. In the present study and in previous studies, the number, content and timing of ostensive signals was highly controlled. In reality, however, a human trying to encourage an animal (or a human) to watch an instructive demonstration would adjust their communication to the addressee's reaction and synchronize their behavior (cf. Bard & Vauclair, 1984). For example, the demonstrator might more frequently and vigorously encourage the addressee to watch if the latter were to turn away and would potentially praise the addressee for paying attention. This can be considered beneficial for at least two reasons. First, reciprocal interactions have been reported to produce neural activation patterns different from those elicited by mere observation of social interactions (Redcay & Schilbach, 2019). Potentially, this indicates that reciprocal interactions more accurately reflect real-life social interactions and the challenges associated with them. Second, highly reciprocal interactions might come closer to the distinctively human mother-infant interactions observed in Bard and Vauclair's study (1984). Consequently, a higher degree of reciprocity might make ostensive communication in experimental settings more realistic and more human-like. However, even if the lack of reciprocity is what prevented pigs' learning from being enhanced by ostension, this raises the question whether pigs' sensitivity might nevertheless be inferior to that of species showing sensitivity even to standardized ostensive signals.

Finally, future studies should aim at equalizing the duration of ostensive and non-ostensive attention-getters, so that potential differences in cueing length can be ruled out as reasons for differential attentiveness or success.

6.4 Conclusion

We found that, independently of their experience with human communication, ostension can enhance pigs' attentiveness to human demonstrations in some tasks. In addition, pig groups differed in their attentiveness independently of ostension, suggesting that older, more trained and more experienced individuals are more attentive to human demonstrations.

Further, pigs were able to learn from both ostensive and non-ostensive human demonstrations in a detour task. However, pigs' learning from human demonstrations was not enhanced by ostension in any task. This may indicate that selection for companionship is indispensable for animal species' learning to be enhanced by human ostensive communication, while domestication for other purposes and individual experience with human communication are insufficient. Alternatively, the experimental paradigms we employed, following previous research on human infants, dogs, cats and horses, might be less suitable for detecting ostension-enhanced learning in pigs. As for attentiveness, we found pronounced ostension-independent group differences in pigs' detour success and in their propensity to commit the A-not-B error. These differences illustrate the role previous experience with humans and with training plays in modulating animals' cognitive performance. In particular, our results once again highlight the importance of enrichment on animals' performance in cognitive tests (cf. Zentall, 2021).

We conclude that, in some contexts, human ostensive communication increases pigs' attentiveness, irrespective of their individual experience with human communication, but that, in contrast to domesticated species selected for companionship, it does not enhance pigs' learning in the tasks we employed. Further research with a wider range of species and experimental paradigms is called for to pinpoint the evolutionary prerequisites and specific contexts that make animals sensitive to "being addressed" by humans.

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Appendix

Appendix A: Comparison between Distances and Barrier Lengths in the Commercial Pigs

Given that the distance between the start box and the bowls (object-choice task) or screens (A-not-B task) was changed midway through the testing for the commercial pigs, we here descriptively compare attentiveness and success between individuals that experienced the short and those that experienced the long distance.

Pigs' attentiveness in the object-choice task for the two groups is plotted in Figure 15. As can be seen from the plot, pigs that were tested with the shorter distance and barrier (i.e., those for which the lengths deviated from the proportion used for the other populations) were more attentive but did not clearly differentiate between conditions, counter to what is reflected in the overall results for the commercial pigs (see 5.1 Object-Choice Task: Attentiveness and in particular Figure 7). Therefore, this sub-sample is unlikely to have generated false positive results regarding differences between conditions and groups.

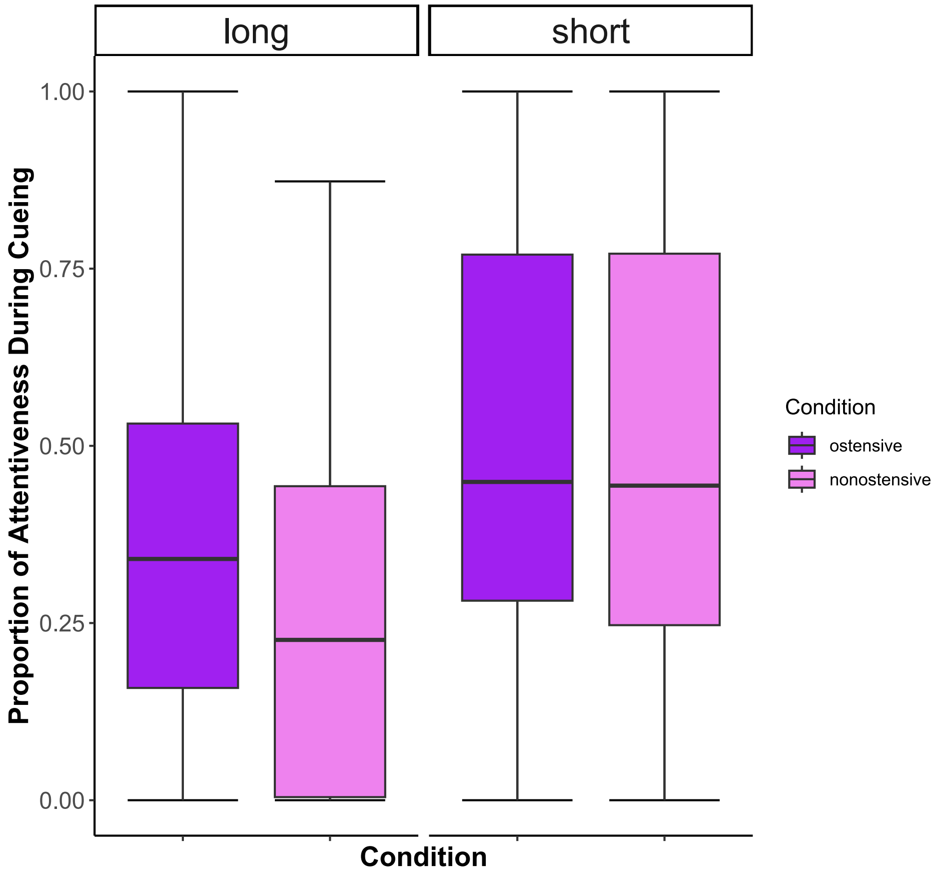

Figure 15: Proportion of attentiveness during the cueing of the object-choice task in the two conditions (ostensive in purple and non-ostensive in pink) for the pigs that were tested with a short distance and short barrier and those that were tested with a long distance and long barrier.

The success of the two groups in the object-choice task can be seen in Figure 16. Despite subtle differences in success, the non-significant results obtained for the main analysis show that the differences between pigs that experienced a long distance and barrier and those that were tested with a shorter one did not distort the overall conclusion.

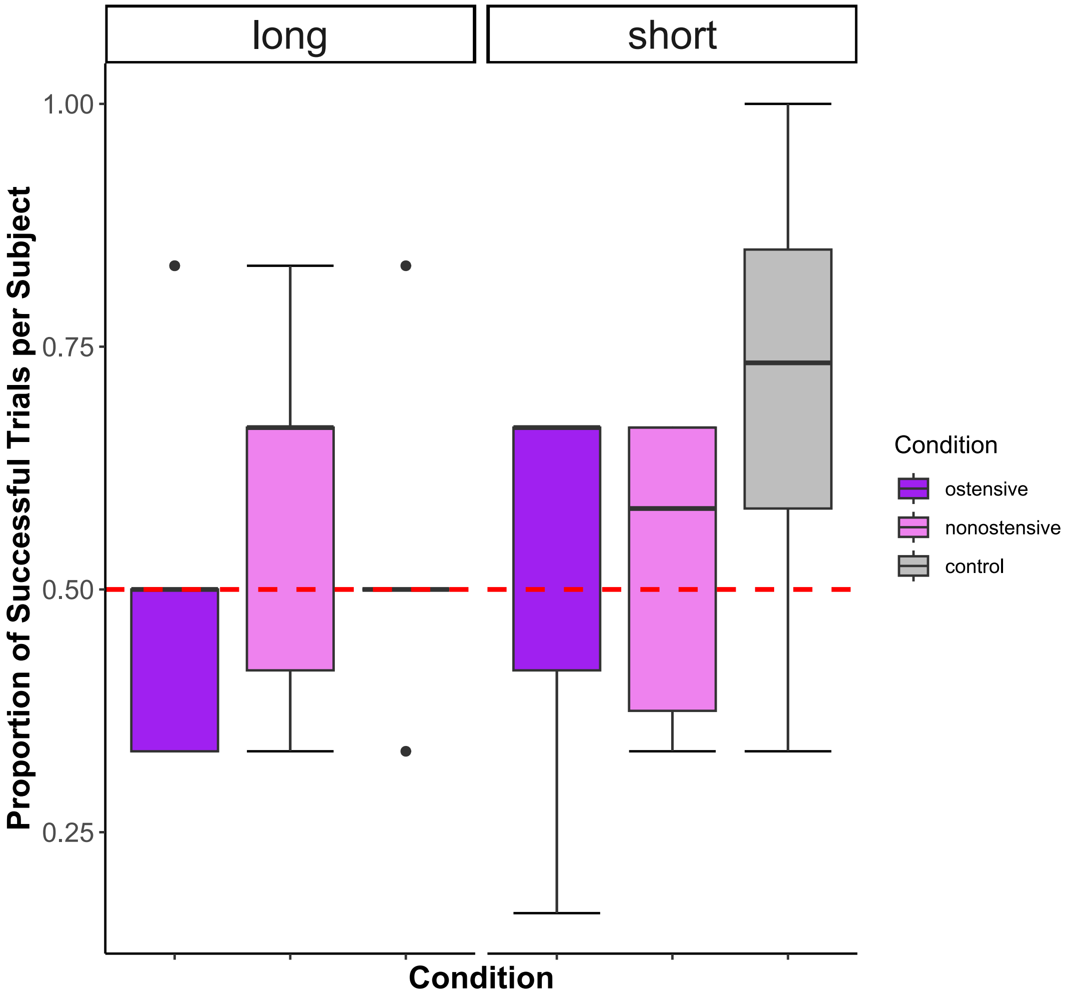

Figure 16: Proportion of successful trials per subject in the object-choice task in the three conditions (ostensive in purple, non-ostensive in pink, control in gray) for the pigs that were tested with a short distance and short barrier and those that were tested with a long distance and long barrier.

The two groups' attentiveness was very similar in the A-not-B task (see Figure 17). Apart from the fact that attentiveness did not significantly differ between conditions in the A-not-B task for the full sample, commercial pigs tested with a shorter barrier show the opposite pattern relative to our predictions. Hence, the difference in distance cannot have biased the overall results towards a more prediction-affirming outcome.

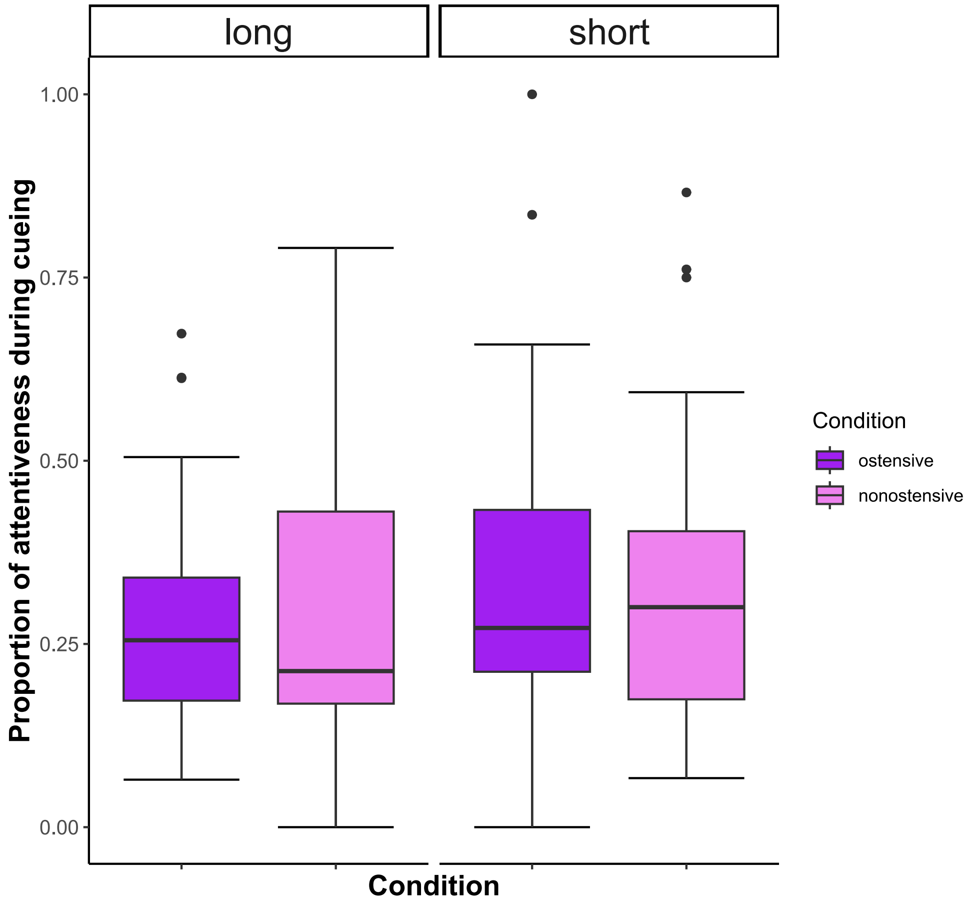

Figure 17: Proportion of attentiveness during cueing in the A-not-B task in the two conditions (ostensive in purple and non-ostensive in pink) for the pigs that were tested with a short distance and short barrier and those that were tested with a long distance and long barrier.

Pigs' success in the A-not-B task is visualized in Figure 18. Again, the pigs for which the distance deviated from the proportion used for the other groups exhibit a behavioral pattern that neither conforms with the overall pattern of results for the commercial pigs, nor with our predictions. That is, pigs that were tested with the shorter distance showed a less pronounced A-not-B error in the crucial ostensive B1 trial than those tested with the longer distance (correct proportion).

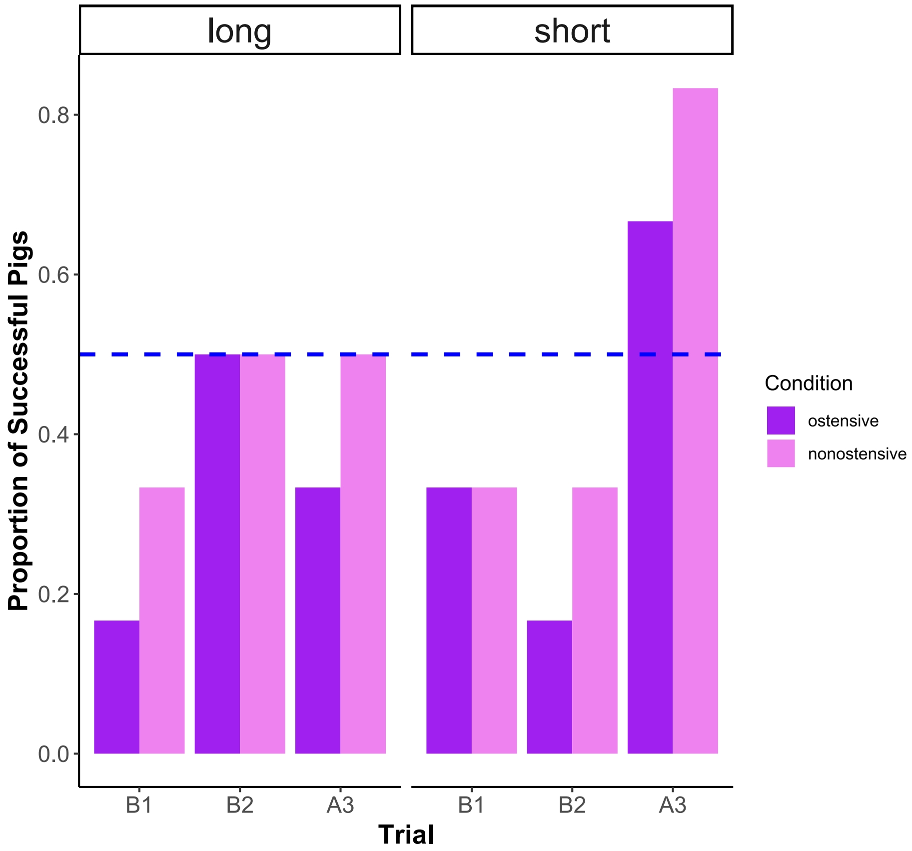

Figure 18: Proportion of successful pigs in the A-not-B task in the two conditions (ostensive in purple and non-ostensive in pink) for the pigs that were tested with a short distance and short barrier and those that were tested with a long distance and long barrier. The dashed blue line indicates chance level (0.5). Only trials B1, B2 and A3 are depicted as trials A1 and A2 were per definition successful and are, therefore, not relevant to the present comparison.

Given the conclusions we can draw from visual inspection of the differences between the two sub-samples within the commercial pig group, we considered the impact of these divergences on our results and the risk of it leading to false positive results negligible, which is why the commercial pigs were treated as one uniform group in the main analyses without taking unequal barrier and distance lengths into account.

Appendix B: Table of Subjects

Table A1: Overview of all pigs that participated in the study. "M" stands for male and "F" for female. "ON" stands for the condition order in which the ostensive condition comes first, while "NO" stands for the reverse. Cells with gray shading indicate that the subject never completed this test and/or that the tests were not analyzed. Length of the barrier/distance only refers to commercial pigs.

Subject	Group	Sex	Date of Birth	Age (in years)	Condition Order Object-Choice	Condition-Order A-not-B and Detour	First Detour Set-up	First A-not-B Set-up	A side	Unsuccessful A trials session 1	Unsuccessful A trials session 2	Distance and barrier length
Meaty	companion	M	05.04.2018	4	ON	NO	mirrorJ	screens	left	1	2	
Borsó	companion	M	14.08.2017	5	ON	NO	J	cardboard	Right	5	1	
Pilo	companion	M	14.09.2017	5	NO	ON	mirrorJ	cardboard	Left	0	0	
Rozi	companion	F	17.07.2015	7	ON	NO	J	screens	Right	2	3	
Sári	companion	F	25.04.2018	4	NO	ON	mirrorJ	screens	Left	6	5	
Lajos	companion	M	23.10.2017	4	ON	NO	mirrorJ	cardboard	Left	2	3	
Bambi	companion	F	27.10.2017	4	ON	NO	mirrorJ	cardboard	Left	4	25	
Töpi	companion	F	29.09.2017	4	NO	ON	J	screens	Right	8	2	
Beauty	lab	F	06.03.2013	10	NO	ON	mirrorJ	cardboard	Left	1	3	
Zeus	lab	M	20.06.2015	7.5	ON	NO	mirrorJ	screens	Left	5	0	
Raya	lab	F	22.06.2015	7.5	NO	ON	J	screens	Right	0	2	

Radomir	lab	M	22.06.2015	7.5	ON	NO	J	cardboard	Right	0	4	
Bibi	lab	F	26.09.2014	8.5	NO	ON	mirrorJ	screens	Left	2	3	
Zampano	lab	M	28.08.2014	8.5	ON	NO	mirrorJ	cardboard	Left	4	0	
Zoe	lab	F	28.08.2014	8.5	NO	ON	J	cardboard	Right	0	5	
Barbarossa	lab	M	20.06.2015	7.5	ON	NO	J	screens	Right	0	0	
Zoltan	lab	M	20.06.2015	7.5	NO	ON	mirrorJ	cardboard	Left	1	9	
Belana	lab	F	20.06.2015	7.5	ON	NO	mirrorJ	screens	Left	1	2	
Rasputin	lab	M	30.08.2014	8.5	NO	ON	J	screens	Right	2	0	
Rosine	lab	F	22.06.2015	7.5	ON	NO	J	cardboard	Right	1	5	
Zardoz	lab	M	20.06.2015	7.5	NO	ON	mirrorJ	screens	Left	1	0	
Bijou	lab	F	26.09.2014	8.5	ON	NO	mirrorJ	cardboard	Left	3	0	
Benjamin	lab	M	26.09.2014	8.5	NO	ON	J	cardboard	Right	2	3	
Zwetschge	lab	F	28.08.2014	8.5	ON	NO	J	screens	Right	0	1	
Radieschen	lab	F	22.06.2015	7.5	NO	ON	mirrorJ	cardboard	Left	3	3	
Romeo	lab	M	30.08.2014	8.5	ON	NO	mirrorJ	screens	Left	5	1	

Bella	lab	F	26.09.2014	8.5	NO	ON	J	screens	Right	NA	NA	
Zazou	lab	M	28.08.2014	8.5	ON	NO	J	cardboard	Right	4	0	
Rapunzel	lab	F	30.08.2014	8.5	NO	ON	mirrorJ	screens	Left	2	2	
Bolero	lab	M	20.06.2015	7.5	ON	NO	mirrorJ	cardboard	Left	5	2	
Blossom	lab	F	20.06.2015	7.5	NO	ON	J	cardboard	Right	0	1	
Rudi	lab	M	30.08.2014	8.5	ON	NO	J	screens	Right	1	0	
Zafira	lab	F	28.08.2014	8.5	ON	NO	mirrorJ	screens	Left	4	1	
Zeppelin	lab	M	20.06.2015	7.5	NO	ON	J	screens	Right	0	1	
Bessy	lab	F	26.09.2014	8.5	ON	NO	J	cardboard	Right	0	0	
Bruno	lab	M	20.06.2015	7.5	NO	ON	mirrorJ	screens	Left	0	0	
Zita	lab	F	20.06.2015	7.5	ON	NO	mirrorJ	cardboard	Left	0	7	
Zacharias	lab	M	28.08.2014	8.5	NO	ON	J	cardboard	Right	1	1	
Blume	lab	F	26.09.2014	8.5	ON	NO	J	screens	Right	0	0	
Sow768	commercial	F	03.10.2020	2.5	ON	NO	mirrorJ	screens	Left	2	0	short
Sow847	commercial	F		1.5	NO	ON	J	screens	Right	0	0	short

Sow842	commercial	F		1.5	ON	NO	J	cardboard	Right	0	0	short
Sow833	commercial	F	02.10.2021	1.5	NO	ON	mirrorJ	cardboard	Left	0	3	short
Sow805	commercial	F		2	ON	NO	J	screens	Right	2	0	Short
Sow801	commercial	F		2	NO	ON	mirrorJ	screens	Left	0	1	Short
Sow832	commercial	F	02.10.2021	1.5	ON	NO	mirrorJ	cardboard	Left	0	1	Long
Sow841	commercial	F	02.10.2021	1.5	NO	ON	J	cardboard	Right	0	0	Long
Sow794	commercial	F	08.05.2021	2	ON	NO	mirrorJ	screens	Left	1	0	Long
Sow797(noTag)	commercial	F	07.05.2021	2	NO	ON	J	screens	Right	6	0	Long
Sow775	commercial	F	09.11.2020	2.5	ON	NO	J	cardboard	Right			Long
Sow897/879	commercial	F	25.03.2022	1	ON	NO	J	screens	Right	2	0	Long
Flora	commercial	F	15.05.2022	1	NO	ON	mirrorJ	screens	Left	1	NA	Long
Sow878	commercial	F	25.03.2022	1	ON	NO	mirrorJ	cardboard	Left	0	2	Long
Sow728	commercial	F	19.01.2020	3	NO	ON	J	cardboard	Right			Long

Appendix C: Supplementary Statistical Information

Full Model Output Attentiveness Object-Choice Task

Table A2: Full model output for the fixed effects of the glmmTMB analyzing the relative attentiveness in the object-choice task. P-values are only given for relevant terms.

Term	Estimate	SE	Z	X^2	df	P[3]	Lower CI	Upper CI
Intercept	-0.597	0.174	-3.438				-0.937	-0.256
Condition.ostensive[1]	0.151884	0.150249	1.011	605.22	1	**< 0.001**	-0.143	0.446
Group.companion	1.804	0.301	5.993	54.31	3	0.085	1.214	2.395
Group.lab	1.904	0.230	8.284				1.453	2.354
z.Condition_order[2]	0.003	0.070	0.048				-0.134	0.141
z.Trial_within_Cond[2]	0.079	0.038	2.079				0.004	0.153
Sex.male	-0.243	0.187	-1.300				-0.610	0.124
Condition.ostensive:Group.companion	-0.096	0.268	-0.356	0.22	2	0.893	-0.621	0.430
Condition.ostensive:Group.lab	0.024	0.191	0.125				-0.351	0.398

[1]Condition was dummy coded for the inclusion as a random slope with “nonostensive” being the reference category.

[2]The variables Condition order and Trial within Condition were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 2 and 0.817 or 3.5 and 1.709, respectively.

[3]p-value obtained using the drop1 function.

Full Model Output Success Object-Choice Task

Table A3: Full model output for the fixed effects of the glmm analyzing success in the object-choice task. No p-values for interactions or single terms were calculated as the full-null model comparison did not yield a significant difference.

Term	Estimate	SE	Z	Lower CI	Upper CI
Intercept	0.196	0.311	0.630	-0.414	0.807
Condition.nonostensive	-0.177	0.418	-0.424	-0.996	0.641
Condition.ostensive[1]	-0.180	0.414	-0.434	-0.992	0.632
Group.companion	-0.429	0.485	-0.886	-1.380	0.521
Group.lab	-0.410	0.308	-1.332	-1.014	0.193
z.Condition_order[2]	0.026	0.131	0.202	-0.230	0.2833
z.Trial_within_Cond[2]	-0.073	0.067	-1.094	-0.205	0.058
Side.right	0.180	0.134	1.347	-0.082	0.442
Sex.male	0.003	0.155	0.016	-0.302	0.307
Condition.nonostensive:Group.companion	0.375	0.602	0.622	-0.806	1.555
Condition.ostensive:Group.companion	0.912	0.604	1.509	-0.273	2.096
Condition.nonostensive:Group.companion	0.260	0.400	0.651	-0.523	1.044
Condition.ostensive:Group.lab	0.364	0.394	0.923	-0.408	1.135

[1]Condition was dummy coded for the inclusion as a random slope with “control” being the reference category.

[2]The variables Condition order and Trial within Condition were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 2 and 0.817 or 3.5 and 1.709, respectively.

Full Model Output Attentiveness A-not-B Task

Table A4: Full model output for the fixed effects of the glmmTMB analyzing the relative attentiveness in the A-not-B task. P-values are only given for the relevant terms.

Term	Estimate	SE	Z	X^2	df	P[3]	Lower CI	Upper CI
Intercept	-0.959	0.204	-4.69				-1.360	-0.559
Condition.ostensive[1]	-0.052	0.145	-0.36	0.572	1	0.449	-0.336	0.233
Group.companion	1.571	0.285	5.15	56.519	2	**< 0.001**	1.013	2.131
Group.lab	2.138	0.229	9.35				1.690	2.587
Trial.A2	0.206	0.116	1.77				-0.022	0.433
Trial.B1	0.281	0.115	2.45				0.056	0.505
Trial.B2	0.290	0.116	2.50				0.062	0.517
Trial.A3	0.317	0.121	2.62				0.080	0.555
z.Session[2]	0.063	0.040	1.58				-0.015	0.141
Sex.male	-0.096	0.180	-0.54				-0.448	0.256
A.side.pigs.view.right	-0.097	0.156	-0.62				-0.402	0.209
Setup.screens	0.118	0.078	1.51				-0.035	0.183
z.WarmUpNumber[2]	0.072	0.057	1.26				-0.039	0.272
Condition.ostensive:Group.companion	0.112	0.235	0.48	0.552	2	0.759	-0.347	0.572
Condition.ostensive:Group.lab	-0.050	0.181	-0.27				-0.405	0.306

[1]Condition was dummy coded for the inclusion as a random slope with “nonostensive” being the reference category.

[2]The variables Session and WarmUpNumber were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 1.49 and 0.500 or 1.95 and 3.057, respectively.

[3]p-value obtained using the drop1 function.

Full Model Output Success A-not-B Task

Table A5: Full model output for the fixed effects of the glmm analyzing success in the A-not-B task. P-values are only given for the relevant terms.

Term	Estimate	SE	Z	X^2	df	P[3]	Lower CI	Upper CI
Intercept	-0.827	0.720	-1.15				-2.238	0.584
Condition.ostensive[1]	-0.448	0.913	-0.49	0.153	1	0.696	-2.238	1.342
Group.companion	0.749	1.039	0.72	10.675	2	**0.005**	-1.289	2.786
Group.lab	-0.261	0.882	-0.30				-1.337	2.021
Trial.B2	0.342	0.856	0.40	28.269	2	**< 0.001**	-1.337	2.021
Trial.A3	1.390	0.875	1.59				-0.326	3.106
z.Session[2]	0.242	0.132	1.84				-0.0155	0.500
A.side.pigs.view.right	0.102	0.261	0.39				-0.409	0.614
Setup.screens	0.186	0.263	0.71				-0.330	0.703
Sex.male	0.133	0.302	0.44				-0.4578	0.724
z.WarumUpNumber	-0.364	0.188	-1.94				-0.733	0.004
z.Attentiveness_relative	0.073	0.2077	0.35				-0.3341	0.480
Condition.ostensive:Group.companion	1.255	1.424	0.88	2.497	2	0.287	-1.536	4.046
Condition.ostensive:Group.lab	-0.226	1.100	-0.21				-2.382	1.929
Condition.ostensive:Trial.B2	0.058	1.250	0.046	1.803	2	0.406	-2.393	2.508
Condition.ostensive:Trial.A3	-0.3196	1.250	-0.26				-2.769	2.130
Group.companion:Trial.B2	-0.859	1.343	-0.64	3.970	4	0.410	-3.492	1.774
Group.lab:Trial.B2	-0.1727	1.027	-0.17				-2.186	1.841
Group.companion:Trial.A3	0.637	1.570	0.406				-2.439	3.713
Group.lab:Trial.A3	0.2065	1.043	0.20				-1.837	2.250
Condition.ostensive:Group.companion:Trial.B2	-0.161	2.026	-0.08	1.827	4	0.768	-4.132	3.810
Condition.ostensive:Group.lab:Trial.B2	1.184	1.495	0.79				-1.746	4.114
Condition.ostensive:Group.companion:Trial.A3	21.25	52420	0.00				-102715.5	102758.0
Condition.ostensive:Group.lab:Trial.A3	0.5496	1.493	0.37				-2.376	3.475

[1]Condition was dummy coded for the inclusion as a random slope with “nonostensive” being the reference category.

[2]The variables Session, WarmUpNumber and Attentiveness_relative were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 1.49 and 0.50, 1.95 and 3.06, or 0.70 and 0.30, respectively.

[3]p-value obtained using the drop1 function.

Full Model Output Attentiveness Detour Task

Table A6: Full model output for the fixed effects of the glmmTMB analyzing the relative attentiveness in the detour task. P-values are only given for the relevant terms.

Term	Estimate	SE	Z	X^2	df	P[3]	Lower CI	Upper CI
Intercept	-0.518	0.222	-2.34				-0.952	-0.084
Condition.nonostensive[1]	-0.461	0.239	-1.93	5.165	1	**0.02**	-0.931	0.007
Group.companion	1.565	0.348	4.50	61.315	2	**< 0.001**	0.884	2.25
Group.lab	2.219	0.268	8.26				1.692	2.745
z.Session[2]	0.058	0.067	0.86				-0.07	0.190
z.Trial.Number	-0.004	0.098	-0.04				-0.196	0.187
Sex.male	-0.319	0.194	-1.64				-0.700	0.062
Setup.mirrorJ	-0.095	0.137	-0.70				-0.364	0.173
Condition.nonostensive:Group.companion	0.100	0.410	0.24	0.650	2	0.772	-0.705	0.904
Condition.nonostensive:Group.lab	0.238	0.299	0.80				-0.349	0.825

[1]Condition was dummy coded for the inclusion as a random slope with "ostensive" being the reference category.

[2]The variables Session and Trial.Number were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 1.50 and 0.501 or 4.99 and 0.816, respectively.

[3]p-value obtained using the drop1 function.

Full Model Output Latency to Reach the Target Detour Task Between Conditions

Table A7: Full model output for the fixed effects of the Cox mixed effects model analyzing the latency to reach the target in the detour task between conditions. P-values are only given for relevant terms.

Term	coef	exp(coef)	se(coef)	Z	X^2	df	P[3]
Group.companion	1.824	6.199	1.66	1.10	33.218	2	**< 0.001**
Group.lab	2.607	13.558	1.247	2.09			
Condition.nonostensive[1]	0.040	1.040	1.696	0.02	0.006	1	0.938
z.TrialNumber[2]	0.520	1.682	1.020	0.51	8.78	1	**0.003**
z.SessionNumber[2]	0.523	1.686	0.184	2.84			
Setup.mirrorJ	-0.473	0.623	0.313	-1.51			
z.Latency_nodemo_average[2]	-1.065	0.345	0.150	-7.11			
z.Attentiveness_relative[2]	-0.320	0.726	0.154	-2.08			
Sex.male	-0.344	0.709	0.202	-1.70			
Group.companion:Condition.nonostensive	-1.196	0.302	2.417	-0.49	0.398	2	0.820
Group.lab:Condition.nonostensive	-0.211	0.810	1.769	-0.12			
Group.companion:z.TrialNumber	-0.975	0.377	1.550	-0.63	0.257	2	0.880
Group.lab:z.TrialNumber	-0.051	0.950	1.057	-0.05			
Condition.nonostensive:z.TrialNumber	-0.528	0.590	1.566	-0.34	0.625	1	0.429
Group.companion:Condition.nonostensive:z.TrialNumber	2.000	7.390	2.257	0.89	0.791	2	0.6732
Group.lab:Condition.nonostensive:z.TrialNumber	0.801	2.228	1.615	0.50			

[1]Condition was dummy coded for inclusion as a random slope with “ostensive” being the reference category.

[2]The variables TrialNumber, SessionNumber, Latency_nodemo_average and Attentiveness_relative were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 4.99 and 0.82 (TrialNumber), 1.50 and 0.50 (SessionNumber), 47.44 and 14.91 (Latency_nodemo_average), and 0.68 and 0.29 (Attentiveness_relative).

[3]p-value obtained via comparison of reduced models.

Full Model Output Latency to Reach the Target Detour Task Between Demonstration and No-Demonstration Trials

Table A8: Full model output for the fixed effects of the Cox mixed effects model analyzing the latency to reach the target in the detour task between the demonstration and no-demonstration trials. P-values are only given for relevant terms.

Term	coef	exp(coef)	se(coef)	Z	X^2	df	P[3]
TrialType.nodemo[1]	0.458	1.581	0.524	0.87			
z.SessionNumber[2]	0.566	1.760	0.409	1.38			
Group.companion	0.386	1.470	0.677	0.57			
Group.lab	2.71	15.160	0.427	6.37			
z.Trial[2]	0.101	1.106	0.063	1.61			
Setup.mirrorJ	-0.008	0.992	0.128	-0.06			
Sex.male	0.052	1.056	0.525	0.39			
TrialType.nodemo:z.SessionNumber	0.054	1.056	0.524	010	< 0.001	1	0.989
TrialType.nodemo:Group.companion	-0.664	0.515	0.928	-0.72	7.111	2	**0.029**
TrialType.nodemo:Group.lab	-1.184	0.306	0.547	-2.16			
z.SessionNumber:Group.companion	0.494	1.639	0.674	0.73	1.295	2	0.523
z.SessionNumber:Group.lab	0.347	1.41	0.421	0.82			
TrialType.nodemo:z.SessionNumber:Group.companion	-0.232	0.793	0.929	-0.25	0.065	2	0.968
TrialType.nodemo:z.SessionNumber:Group.lab	-0.049	0.952	0.548	-0.09			

[1]TrialType was dummy coded for inclusion as a random slope with "demo" being the reference category.

[2]The variables TrialNumber and SessionNumber were z-transformed to a mean of 0 and a standard deviation of 1, with the untransformed mean and standard deviation being 1.997 and 0.816 or 1.501 and 0.500, respectively.

[3]p-value obtained via comparison of reduced models.