Rocz. Nauk. Zoot., Vol. 50, no. 2 (2023) 131-148 *DOI: 10.58146/kgda-cv04*

COGNITIVE PROCESSES, BEHAVIOUR AND INTELLIGENCE OF PIGS

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Source of funding: this work has been funded by the research centre's statutory activities

Abstract

The objective of this study is to demonstrate specific cognitive processes accompanied by behavioural traits that support the presence of intelligence in pigs. Phylogenetic analysis reveals a connection between intelligence and the level of advancement of the nervous system and the sensory organs, including olfactory and gustatory, auditory, visual, as well as tactile perception. Optimal utilisation of well-developed senses greatly influences the cognitive processes of learning and memory in pigs. These animals possess the ability to perceive and retain information, which they can then apply based on their interactions with other members of their social group. Pigs demonstrate various behaviours and patterns of interaction with other species, including engaging in competitive behaviour. While they exhibit social behaviour, further research is needed to fully understand the cognitive and emotional traits that govern their sense of community.

Keywords: pigs, cognitive processes, behaviour, personality

Introduction

Through the process of domestication, pigs have developed adaptive behaviour to ensure their survival. Pigs express and fulfil their needs through the development and refinement of systems, such as the nervous system and organs. The biological systems consist of cells and tissues that interact and collaborate to carry out specific essential functions. The nervous system facilitates the transmission of information between the organism and its external environment, while also regulating and synchronising physiological functions. The cerebral cortex comprises motor, associative, and sensory regions, with the sensory areas responsible for perceiving somatic and visceral sensations, as well as olfactory, gustatory, auditory, and visual perceptions. The somatic system receives external stimuli and controls voluntary actions, while the autonomic system receives signals from the internal environment. The two systems exhibit antagonistic behaviour towards each other (Krzymowski and Przała, 2015).

Pigs exhibit complex social behaviour and have a natural inclination to live in groups. These animals' behaviour is influenced by emotions, and they possess distinct basic emotional systems, including curiosity, rage, fear, desire, care, panic, and play. Pigs partition their habitat and allocate different areas for various activities such as resting, feeding, and defecating. Pigs possess a strong instinct for foraging and exploration. Foraging is an innate behaviour that certain individuals engage in up to 60 times per day (Reinhardt and Reinhardt, 2002). Pigs

identify one another through visual, auditory, tactile, and olfactory means. Their gastrointestinal, exploratory, social, and sexual behaviour is unique (Nowicki and Klocek, 2019).

Stressors, such as changes in temperature (physical factors) or limited access to food (physiological factors) can cause stress in pigs. Its consequences result in changes to the function of the circulatory, endocrine, immune, central nervous, and reproductive systems. Complete restoration of homeostasis in the functioning of an organism typically does not occur until a few days after the stressor is eliminated (Obernier and Baldwin, 2006).

Pigs are regarded as intelligent animals. They possess exceptional spatial orientation, demonstrated by their ability to navigate back to their destination even when several kilometres away. Similar to dogs, piglets respond to their given name, which occurs as early as 2-3 weeks after birth. Pigs, similar to humans, experience dreams during their sleep. They acquire knowledge through the process of observing and analysing each other's behaviour..(https://sentientmedia.org/pig-intelligence/).

Brain and senses

Neuroscientific research suggests that the structure and size of the pig brain closely resemble that of the human brain, exhibiting a significant level of development and size. A great deal of information has been gathered regarding the structure and chemical processes within the pig brain, yet our understanding of the cortical functions of this organ remains limited (Lind et al., 2007). Cortical neurons in humans and domestic pigs do not undergo postnatal development. Jelsing et al. (2006) conducted an experiment to explore the cortex by estimating the quantity of neurons within it. The researchers evaluated the change in the quantity of cortical neurons in two different breeds of pigs, both at birth and during adulthood. In the Danish sag hog, the number reached 425 million at birth and remained unchanged in adulthood, whereas in the miniature pig, the corresponding numbers were 253 and 324 million, respectively. The observed quantitative changes highlight the necessity for further research in this domain, given that the cerebral cortex plays a pivotal role in the majority of conscious behaviour.

Vision is the ability to detect and interpret light stimuli from the surroundings. The eyeball serves as the sensory organ responsible for the visual perception of shapes, colours, and the estimation of distances. The anatomical structure of the pig's eye and the human eye are analogous, suggesting that this structure enables the perception of a complete spectrum of colours. Nonetheless, the interpretation of visual stimuli is not solely determined by the eye's anatomy, but rather by the comprehensive network of interconnections between light signals, the optic nerves, and the brain. Pigs possess a visual field spanning 310 degrees, and when utilising binocular vision, the visual angle narrows down to a range of 35-50 degrees (Klocek and Mielczarek, 2008). The visible spectrum for pigs spans from 465 to 689 nm, as reported by Signoret et al. in 1975. The sense of vision is highly developed and plays a crucial role in perceiving the environment. However, the quality of sight is influenced by factors such as illumination, colour, distance, and size (Koba and Tanida, 2001). The pig's eye lacks complete accommodative capacity, or in other words the ability to adjust the focus of an image. Pigs are prone to perceive objects in their surroundings as two-dimensional surfaces with distinct colours. Pigs possess the ability to differentiate between colours and exhibit a preference for specific colours (Klocek et al., 2016). However, their ability to discriminate colours is limited to certain specific cases. They are able to differentiate between the colours blue and green, but it is unlikely that they can differentiate between red and green (Koba and Tanida, 2001).

The senses that have facilitated pigs' adaptation to their lifestyle are smell and taste. Pigs possess a heightened olfactory ability, meaning they have a powerful sense of smell. The olfactory receptors are situated in the dorsolateral mucosa of the nasal cavity and in the mucosa

of the nasal septum (Dyce et al., 2011). Olfactory signals, detected through the sense of smell, serve as a method of communication by conveying social information such as sexual arousal, social identity, and inclination towards aggression. Pigs use secreted pheromones to discern the sex and reproductive status of others (Adamczyk et al., 2015). The animals rely on both their sense of smell and sight to facilitate learning and memorisation (Croney et al., 2003).

Taste receptors, known as taste buds, are found in the walls of taste papillae on the tongue, as well as in the buccal mucosa, soft palate, and posterior pharyngeal wall (Dyce et al., 2011). Pigs possess approximately 15,000 taste buds, as reported by Krzymowski and Przała in 2015. Pigs possess taste receptors that are highly responsive to a diverse array of flavours, encompassing the taste sensations commonly perceived by humans as bitter, salty, sweet, and sour (Jones et al., 2000). The addition of appealing flavours to pig feed has the capacity to enhance feed consumption, but solely when the animals are provided with a selection of feed options. According to Jacela et al. (2010), pigs have a preference for cheese, fruit, sweets, and meat. The memory of a flavour, akin to the recollection of the aroma of a food that previously induced sickness, elicits a repulsion towards that food and prompts the animal to reject it later in life. Food also evokes positive associations that are retained in memory.

Pigs utilise their hearing abilities not only to perceive sounds from their surroundings, but primarily to facilitate communication among members of their social group. The vocalisations emitted by the pigs, including grunting, snarling and squeaking, are dependent upon and exhibit variability based on the specific situations, such as distress, greeting, or calling. The audible frequency range for these animals is 42-40600 Hz (Heffner, 1998). Pigs possess the ability to detect and interpret sounds in their surroundings, including high-frequency ultrasound, and they exhibit a relatively low sensitivity to noise. Nevertheless, it is advisable to refrain from exposing the animals to abrupt and excessively loud sounds, as such stimuli can cause them to feel stressed (Marchant et al., 2001; Bollen et al., 2010; Nowicki and Klocek, 2019).

Intelligence

Intelligence is defined as the ability to utilise acquired skills effectively and to exhibit an efficient pattern of behaviour in novel and unexpected circumstances (Sadowski, 2022). The phenomenon has a hereditary and environmental basis and exhibits a wide range of variations among different species (Junkiert-Czarnecka and Haus, 2016). There exist variations in cognitive ability among individuals of the same species. Phylogenetic analysis suggests a correlation between intelligence and the developmental phase of the nervous system (Sadowski, 2022). When a person is in a hostile environment, they are more likely to exhibit intelligent behaviour when faced with new and unfamiliar situations (Kaleta, 2007). According to Wynne and Udell (2013), intelligence is characterised as a diverse range of abilities that enable individuals to effectively overcome challenges. Various species have encountered distinct obstacles and difficulties, resulting in the development of unique and distinctive adaptive abilities. Intelligence encompasses the cognitive ability to engage in multidimensional and exploratory thinking. This process involves evaluating perceived events and objects based on their function, structure, and cause-effect interrelations (Sadowski, 2022). This process takes previous experience into account.

Concrete and abstract thinking can be differentiated based on their level of complexity, with abstract thinking being a unique characteristic of humans. Pigs, along with other advanced animals, demonstrate concrete thinking, which is also referred to as picture-motor or sensorimotor thinking. The animal perceives a specific situation and reacts by displaying a suitable behaviour (Sadowski, 2022).

Pigs in the animal world

Pigs are intelligent and sociable creatures, displaying intricate maternal, communicative, and affiliative behaviours. These behaviours involve expressing closeness and interest through touch, physical contact, and eye contact. They possess the capacity to engage in mutual communication, acquire knowledge through past experiences, and establish associations between novel information and previously stored memories (Ŝpinka, 2009).

It is problematic to fully support the categorisation of various animal species based on their ability and intelligence, primarily due to the diverse environmental factors that impact animals. However, the insights gained from such rankings can serve as a valuable addition to the information gathered through behavioural studies by scientists. The rankings lack uniform standards and, as a result, lack authority. The animal species listed in order of increasing intelligence are squirrel, squid, crow, dog, pig, parrot, elephant, dolphin, and monkey (source: https://www.national-geographic.pl/artykul/najmadrzejsze-zwierzeta-10-najbardziej-inteligentnych-gatunkow). According to a ranking in order of decreasing intelligence, pigs are ranked higher than chimpanzees, dolphins, elephants, and dogs. They are then followed by octopuses, rats, ravens, crows, squirrels, and pigeons. This ranking can be found at http://nieistotna.pl/ciekawostki/most-intelligent-animals. In another scenario, the rankings of animals vary slightly. In ascending order, the top positions are held by orangutans, bottlenose dolphins, chimpanzees, elephants, parrots, octopuses, followed by pigs, crows, pigeons, and rats (source: https://a-z-animals.com/blog/the-10-smartest-animals-in-the-world/). Pigs consistently exhibit high intelligence in lists that use intelligence as a classification criterion.

Behaviour of pigs

Pigs possess a distinctive ability to acquire knowledge from past events, retain it, and establish connections between new information and their existing memories. According to Ekesbo (2011), a pig can develop the ability to differentiate between individuals who are known to them and those who are not, based on different stimuli such as the colour of their clothing. The test environment significantly impacts, either positively or negatively, the individual pig's capacity to solve the assigned tasks (Sneddon et al., 2000).

Hidden objects, object recognition

Object constancy refers to the cognitive understanding that an object continues to exist even when it is no longer visible to the observer (Wynne and Udell, 2013). Possessing this ability is crucial for both wildlife and domesticated animals. It enables the animal to track the movements of a predator, prey, or food, even when it is not visible (Nawroth et al., 2013). There is a difference between 'visible movement' and 'invisible movement,' and young pigs are able to comprehend the former.

Object recognition learning refers to the capacity to differentiate between stimuli or objects by considering their distinctive characteristics, which is achieved through conditioned reinforcements (Kehoe, 2008). It serves as the foundation for other types of mental processes. Object recognition enables the process of categorisation and visualisation, which in turn can serve as the basis for other sophisticated abilities. Every animal possesses a certain degree of aptitude for acquiring the skill of identifying and differentiating objects, ranging from basic to complex to abstract. This capacity has been proven in avian species, particularly pigeons, as well as in mammals such as rodents, dogs, and primates (Matsuzawa, 2001; Huber et al., 2005; Zentall and Wasserman, 2006; Range et al., 2008; Wynne and Udell, 2013).

Pigs show advanced object recognition abilities in tasks that demanded excellent recall skills, suggesting a substantial long-term memory capacity in these creatures (Tanida and

Nagano, 1998; Croney et al, 2003; Gifford et al, 2007). According to Gifford et al. (2007), when pigs were observed for their natural reaction to new or familiar objects, they were able to remember the object for a minimum of 5 days after being exposed to it for 2 days. Additionally, pigs displayed a preference for new objects compared to familiar ones. Pigs possess the ability to employ one or both of their senses concurrently, such as sight and smell, particularly when engaging in activities like foraging. Instead of depending solely on memory to locate food, they can also utilise specific food colours and odours to locate the source of food. These animals are capable of differentiation through two distinct mechanisms (Croney et al., 2003).

A study undertaken by Cerbulis (1994) with two Vietnamese pot-bellied pigs revealed their understanding of gestural and verbal symbols associated with various objects (frisbee, ball, dumbbells) and activities (sitting, fetching, jumping). The pig experiment was conducted based on studies concerning dolphins and sea lions. These animals possess the ability to effectively comprehend the meaningful and sequential aspects of artificial language through visual and auditory stimuli (Herman, 1987; Herman et al., 1989; Schusterman, 1993). The pigs acquired the ability to identify patterns of symbols representing actions and objects, such as 'go and get frisbee'. By doing this, they differentiated among three objects and learned to execute actions on objects that had been previously shown to them. They then proceeded to executed assigned activity-object tasks. Similar to dolphins, they demonstrated the ability to differentiate between an intricate triple-choice object and a combination of an object and an activity (Cerbulis, 1994).

Learning and memory. Cognitive abilities and food acquisition

Animals possess a set of adaptive traits that involve the capacity to identify and retain information about the external environment, and the ability to utilise this knowledge. This function is commonly known as spatial memory. The development of memory is tightly connected to the evolutionary expansion of the brain and the emergence of novel structures dedicated to distinct memory functions. The hippocampus in mammals is responsible for their spatial memory (Czajkowski, 2015). Spatial cognition encompasses the cognitive processes involved in acquiring, retaining, organising, and utilising information about the spatial aspects of one's surroundings, such as navigation and the ability to differentiate and prioritise the positions of objects. Spatial learning is associated with both short- and long-term memory. It supports the formation of cognitive maps, which are mental representations of the environment and the spatial arrangement of objects within it. It supports various strategic behaviours in space, such as collecting food or movement (Balda and Kamil, 2002; Shettleworth, 2002). Rodents (Bird et al., 2003) and fish (Brown, 2015) exhibit navigational and spatial foraging skills. Dogs also demonstrate spatial navigation and search capabilities through the use of cognitive maps (Bensky et al., 2013). Chimpanzees and other primates possess spatial-navigation memory and learning capabilities as well (Garber and Dolins, 2014).

Pigs exhibit a diverse array of social behaviours, possess complex cognitive capabilities, and demonstrate a notable level of intelligence, which can be likened to that of primates in certain respects. The processing of stimuli through their sophisticated sensory systems is crucial in the acquisition and retention of knowledge and recollection. Pigs possess both short-term and long-term memory capabilities. By engaging in locomotor play, these mammals exhibit social interaction, exploration, and emotional development. Pigs possess the cognitive ability to acquire knowledge from previous encounters, differentiate between various individuals, including those within their own species and those belonging to other species. They utilise spatial data and engage in competition with one another. They possess the ability to adopt a perspective, or in other words the viewpoint of another individual. These animals' capacity to perceive the passage of time through episodic memory is not well-defined. Pigs are believed to possess a certain degree of self-awareness, placing them among highly intelligent animals.

Further research and observations are necessary to consider the unique characteristics of the species and gain a comprehensive understanding of the cognitive abilities of pigs.

Roelofs et al. (2018) performed an experiment that revealed significant implications for breeding practices in commercial pig production. Additionally, the findings are remarkable in relation to cognitive disorders in humans. The process of selectively breeding pigs for high fertility (large litters) has resulted in an increasing number of piglets with low body weight (LBW) (Rutherford et al., 2013). LBW piglets are less likely to survive before weaning (Galiot et al., 2018). However, a considerable proportion of these piglets manage to reach the age of 5-6 months, at which stage they are earmarked for slaughter (Calderón Díaz et al., 2017). Low birth weight in humans is associated with an elevated risk of long-term cognitive impairment. Prior studies have yielded conflicting results regarding the impact of low birth weight on cognitive function (Gieling et al, 2012; Radlowski et al, 2014; Lindström et al, 2017). Therefore, the objective of the study conducted by Roelofs et al. (2018) was to assess the impact of LBW on the cognitive development of pigs. This was achieved by observing a substantial group of animals (a total of 40 animals), measuring acute and chronic stress responses in piglets through cortisol concentrations (with 20 animals in the LBW group and 20 animals in the high body weight group – HBW), and testing both female and male pigs (with 10 boars and 10 gilts in both the LBW and HBW groups). During the experiment, the pigs had to learn and memorise the place where food treats were hidden. Following the pig's successful completion of the task, the hiding places were changed. The test enabled the concurrent evaluation of memory, motivation, exploration, and behavioural adaptability. The statistical models employed for analysis unveiled a temporary decline in the reference memory performance in the LBW pigs. Specifically, they encountered greater challenges when performing the reward search task. LBW piglets exhibited elevated pre-weaning cortisol levels in comparison to their HBW counterparts. Measurements, including stress levels, were not influenced by sex. The study authors determined that the improved housing conditions implemented during the study positively impacted the cognitive development of the piglets involved in the experiment. The findings suggest that pigs with low birth weight experience a detrimental effect on their cognitive abilities following the weaning process. This could potentially impact their well-being, as pigs require cognitive abilities to acquire the knowledge necessary to appropriately react to their surroundings. Pigs possess a natural inclination to investigate their surroundings and exhibit a profound inquisitiveness, along with the instinctive behaviour of foraging. Exploration primarily occurs at ground level and targets any objects encountered on the ground. Pigs are highly skilled at utilising spatial information, as they dedicate a significant portion of their time to foraging. They demonstrate exceptional proficiency in utilising it while acquiring the ability to navigate mazes (Siegford et al., 2008). They exhibit a predilection for frequenting locations that offer larger quantities of food (Held et al., 2005). Upon acquiring information about two distinct food sources with varying quantities of food, the individuals proceed to revisit the location with a greater amount of food (Mendl et al., 2010). They possess the ability to differentiate and retain information about specific locales associated with food of varying worth (Cutini and Bonato, 2012). Pigs have advanced cognitive capabilities and demonstrate strong memory retention for food locations. Additionally, they can enhance their awareness of food location through assistance from other individuals. Ravens, chimpanzees, and Mangaba monkeys show similar behaviour, as noted by Mendl et al. (2010). However, the specific mechanisms behind this behaviour in pigs have not been definitively established.

The aim of the study conducted by Croney et al. (2003) was to examine the capacity of miniature pigs to utilise visual, olfactory, and spatial cues in order to locate a food source in an unfamiliar setting. The experiment aimed to ascertain the significance of various senses in pigs' foraging behaviour and indirectly evaluate their cognitive capabilities, given the inconsistent and conflicting findings of previous studies on similar subjects. Kilgour (1987) proposed that

pigs possess the capacity to acquire proficiency in complex tasks that involve spatial orientation and multiple options. However, the initial challenges faced by the animal have an adverse impact on its ability to comprehend subsequent tasks. Laughlin et al. (1999) established that pigs' spatial memory can be adversely affected by stressful circumstances. Croney et al. (2003) demonstrated that the olfactory sense exhibited greater reliability than vision in accurately identifying food location cues. The authors also verified the pigs' capacity to correctly interpret cues when faced with multiple options – the higher the number of options, the better the animals performed. During the pigs' foraging, learning, and exploration activities, both their sense of smell and sight, operating simultaneously, have a significant impact. This statement contradicts the thesis put forth by Klopfer (1966), postulating that pigs lack the capacity to acquire skills or demonstrate the use of visual stimuli while foraging.

Play

Play is linked to creativity and innovation, and serves as the basis for nuanced cognitive and social skills (Bateson, 1955). Social play, driven by curiosity and specific preferences, facilitates the formation of novel interactions and situations that are crucial for the development of social mammals. This phenomenon is observed in primates, dogs, dolphins, birds, and pigs, which are cognitively complex and adaptable species. Play behaviour has been documented in fish, reptiles, and octopuses.

Pigs enjoy participating in social play and engaging in object play (Horback, 2014). Object play behaviour encompasses the actions of shaking or carrying an object, such as a ball or stick, as described by Newberry et al. (1988), Bolhuis et al. (2005), and Dudink et al. (2006). Locomotor play encompasses activities such as head tossing, running, jumping, hopping, scratching, and turning (Martin et al., 2015). While engaging in play, pigs fulfil their instinctive drive for exploration and experience developmental growth. Pigs engage in social interactions, such as pushing, fighting, and chasing one another, during locomotor play (Horback, 2014). By offering rewards during plays, diverse outcomes were achieved, thereby establishing a foundation for future investigations in this domain, as noted by Lidfors et al. (2021). Play is most effectively encouraged by a diverse range of intricate, functional, and sustainable objects and materials (Telkanranta et al., 2014; Martin et al., 2015). Their presence in animal habitats is crucial, as inadequate exploration can result in behavioural disorders (Pedersen et al., 2014; Telkanranta et al., 2014). Telkanranta and Valros (2020) advocate for conducting research on the impact of olfactory, gustatory, and tactile stimuli on pigs, as the provision of objects and materials for pigs to interact with and explore has a significant influence on their emotional development.

Communication

Pigs engage in communication on two distinct levels. The two forms of communication discussed are body language, as studied by Hafez and Signoret in 1969, and verbal communication along with its associated vocalisation, as explored by Houpt in 2011. Body language primarily pertains to the social structure within a group and aggressive interactions. Individuals assume a stance, with dominant individuals displaying a posture that signifies power and strength, standing upright, while subordinate individuals adopt a posture of submission and defeat, lowering their head, retreating, and fleeing. Verbal communication, which involves the creation of sounds with different pitch, volume, and tone using the vocal apparatus known as the larynx, is equally important. Pigs emit various distinct sounds, such as brief or prolonged sharp grunts, bark-like noises, and squeaks, which vary according to the situation or circumstances. Pigs possess a highly developed auditory sense, however, their external ear's anatomical structure requires them to rotate their head for more precise sound localization (Dubois, 2006).

Cognitive abilities and recognition of individuals of the same species

Social cognition relies on cognitive abilities and intellect. A positive correlation exists between various cognitive abilities and social complexity in groups, such as primates, birds, dolphins, and whales. Domesticated and wild pigs exhibit social behaviour, but there is limited knowledge regarding the specific ways in which these abilities are expressed in their natural habitats, as well as the cognitive and emotional capacities that underpin their sociability. The capacity to differentiate among individuals serves as the basis for social interactions, hierarchies, and reactions towards familiar or unfamiliar individuals. Identifying individuals is a necessary condition for the subtler capabilities of genuine understanding of the individual.

Pigs, like other socially complex creatures, have the ability to distinguish between members of their own species and show a preference for familiar individuals over strangers (McLeman et al. 2005). According to Mendl et al. (2002), young pigs have the ability to identify familiar and unfamiliar individuals solely based on urine samples. Even after being exposed to a low concentration of ammonia (36 ppm) that impairs their sense of smell, they continued to utilise their olfactory capabilities (Kristensen et al., 2001). Pigs, similar to dogs, utilise auditory signals alongside their sense of smell to differentiate individuals among members of their species (Molnar et al., 2009). Sows exhibit heightened responsiveness, specifically towards auditory cues emitted by their own piglets, suggesting their ability to differentiate their offspring from other piglets solely based on sound (Illmann et al., 2002). Pigs demonstrate a notable capacity to effectively differentiate between individuals within their own species, employing various signals in diverse circumstances.

Being able to differentiate between individuals of a different species may suggest the presence of advanced cognitive capabilities. Dogs possess the ability to differentiate between different humans and interpret their facial cues (Nagasawa et al., 2011). Pigs, unlike dogs, have not undergone selective breeding for human companionship and work, but rather solely for use in slaughter. However, observations of young miniature pigs (Tanida and Nagano, 1998) have confirmed that pigs are capable of distinguishing between familiar and unfamiliar humans. The animals employed olfaction, vision, and audition for recognition purposes. The study observed variations in the signals employed by individuals. The test revealed that smell was the least effective sensory tool. Evidence demonstrated that pigs utilised past encounters, such as being lifted and provided with rewards, to differentiate between two individuals. Pigs exhibit decision-making abilities by distinguishing individuals based on variations in physique and facial characteristics (Koba and Tanida, 2001).

Pig behaviour and intelligence levels

Ability to adopt a point of view

Adopting the perspective of another individual, also known as Machiavellian intelligence, is a sophisticated mental ability that underlies social cognition. It is defined as intentional tactical manoeuvres, such as deception and manipulation. It is widely believed to be the primary factor influencing intelligence in primates, including dogs. Perspective-taking in various species is linked to several cognitive capacities, such as self-awareness and empathy (Whiten and Byrne, 1997; Sadowski, 2022).

Pigs demonstrate behaviour and interaction patterns that resemble those observed in primates, specifically great apes and certain birds (Held et al., 2010; Mendl et al., 2010). Pigs demonstrate sophisticated skills in exploiting and manipulating members of their own species in order to gain an advantage in social foraging scenarios, such as searching for concealed food. This was confirmed by Held et al. (2010) through foraging experiments conducted with pairs of pigs. Both pigs and primates exhibit advanced levels of perspective-taking, as demonstrated by their complex and sophisticated social competitive behaviour (Mendl et al., 2010). Pigs

exhibit sensitivity to the attentional state of humans, displaying a preference for humans who are attentive (Nawroth et al., 2013).

Social and non-social cognition

Social cognition refers to the utilisation of social cognitive abilities, which serves as the foundation for the complexity of cognitive function and intelligence (Sadowski, 2022). There exists compelling evidence indicating a strong and positive correlation between different cognitive abilities and measures of social complexity in groups of animals, including primates, birds, and cetaceans. Wild and domestic pigs exhibit social behaviour, however, there is limited understanding regarding the cognitive and emotional capacities that influence their social interactions. Pigs may possess a level of social complexity comparable to other highly intelligent animals. Early socialisation of piglets is crucial for their subsequent social development. Pre-weaning socialisation has been demonstrated to have an equally significant influence on cognitive abilities in later stages of life. The findings of this study indicate that pre-weaning socialisation has an impact on various aspects of social cognitive development, as demonstrated by the evidence obtained from the social preference test (Weller et al., 2020).

Non-social cognition pertains to the manner in which animals perceive and analyse the physical aspects of their surroundings. It includes the application of physical problem-solving, object identification, spatial cognition, and other aspects of learning and memory in relation to physical objects, including the perception of time. Animals possess internal mechanisms of synchronisation that aid in their ability to perceive the time of day and anticipate the occurrence of an event (Gallistel, 1994). They exhibit a proficiency in episodic memory. Animals possess the ability to recall information about what, where, and when specific events occurred, even after a significant amount of time has passed, ranging from hours to weeks or even years (Martin-Ordas et al., 2010, 2013). Nevertheless, the findings from various research groups (Špinka et al, 1998; Ferguson et al, 2009; Imfeld-Mueller et al, 2011) regarding pigs were inconclusive and failed to definitively address the issue of time perception in this species. However, they do provide some insight and highlight the necessity for additional research in this area.

Self-awareness

The ability to recognise oneself means that the examined individual possesses an understanding of its own uniqueness as well as self-perception; the mirror test fulfils this objective (Wynne and Udell, 2013). All species of great apes, Asian elephants, bottlenose dolphins, and magpies underwent the self-recognition test. Pigs, dogs, and rhesus macaques have demonstrated the ability to use mirrors to solve problems and comprehend their spatial orientation in relation to other objects (Rajala et al., 2010).

Pigs do not show explicit self-recognition, but are able to use the information they see in the mirror (Broom et al., 2009). Some individuals in the test made repetitive movements and looked at themselves in the mirror, stepped back and changed their body position in relation to the mirror, or made alternate movements with their limbs, switching from leg to leg. This behaviour resembled the checking movements exhibited by other animals – elephants, dolphins and chimpanzees – that passed the mirror test. Further research is needed to determine the reliability of mirror-mediated spatial abilities in pigs and whether they engage in activity related to their own bodies as well as mirroring behaviour (Gieling et al., 2014).

The pigs manipulate a modified joystick to control the movement of the cursor on the screen. Operating the joystick to accomplish a desired outcome likely requires the complex skill of causality, which means the ability to identify actions that one has caused oneself. Pigs, although they have limitations in terms of dexterity and visual ability, are capable of completing the task (Croney, 1999). Chimpanzees, like humans, possess this capability (Kaneko and

Tomonaga, 2011), enabling them to differentiate between a computer cursor under their control and a motion triggered by another individual.

More research is required to identify the precise manner in which pigs respond to assigned tasks in order to establish their self-awareness and self-efficacy. Croney and Boysen (2021) conducted a study examining the aptitude of two Yucatan micro-pigs and two Yorkshire pigs (*Sus scrofa*) to complete a video game task using a joystick. The pigs underwent training to operate a joystick, which allowed them to manipulate the movement of a cursor exhibited on a computer monitor. The pigs were required to manipulate the cursor in order to come into contact with targets that were randomly positioned on the monitor. When the cursor made contact with a target, the animals received a reward. Successful completion of the video task necessitated a comprehensive grasp of the task's concepts and well-honed motor skills. Based on the conclusive findings, pigs possess the capability to carry out video game tasks controlled by a joystick, although with certain limitations in terms of dexterity and vision. The constraints of the joystick underscore the necessity for employing touchscreens or other sophisticated computer-interface technologies in future studies on the cognitive capacities of pigs.

Emotions

Emotions encompass a range of behavioural, neurophysiological, cognitive, and conscious subjective processes (Paul et al., 2005). They have the ability to influence other processes through the manipulation of attention, decision-making, and memory. Emotions are impacted by cognitive abilities, situational awareness, and empathy towards the experiences of others. There is a strong connection between emotions and cognitive functions, as demonstrated by several studies (Paul et al, 2005; Ohl et al, 2008; Mendl et al, 2009). Occasionally, it is impossible to provide a precise definition of emotion.

Emotions have a collective impact on multiple individuals within a group. Emotional contagion is regarded as a rudimentary manifestation of empathy, which involves the capacity to experience the emotional condition of another person from their point of view (de Waal, 2008). Emotional contagion is likely the most ancient form of empathy in terms of evolutionary development. De Waal (2008) asserts that empathy serves as the foundation of compassion and entails adopting a specific viewpoint. This emotion is present in various socially complex groups, including dogs, wolves, great apes, humans, and pigs. Emotional contagion allows social animals, such as pigs, to detect and react to social cues related to significant situations.

Reimert et al. (2014) conducted a study on the subject of emotion, where they trained pigs to expect either a positive event (food) or a negative event (social isolation) by using Johann Sebastian Bach's musical pieces (positive event) and a military march (negative event), or the opposite. The trained pigs revealed their acquired knowledge, which manifested as either positive behaviour (engaging in play, wagging their tails, and emitting grunts) or negative behaviour indicative of stress (being in an alert state, flattening their ears, urinating, and defecating). An experiment was conducted to determine whether untrained pigs would exhibit a response to the behaviour of a trained pig upon hearing music that indicated a positive or negative test outcome. The untrained pig exhibited heightened vigilance in the company of the previously trained pigs, as evidenced by its backward-pointing ears. The pigs responded not only to the auditory stimuli of the music, but also to the behaviour of their fellow pigs. The study demonstrated that pigs possess the ability to perceive and respond to the emotional states of their fellow conspecifics within the social group. Reimert et al. (2014) discovered evidence of emotional contagion in pigs. Further research could provide a clearer understanding of the correlation between emotion and empathy in pigs. Murphy et al. (2014, 2021) contend that the diverse play behaviours exhibited by pigs could serve as valuable means for investigating emotion. Specifically, object play and different types of social play are considered indirect indicators of emotion.

Animals, including pigs, exhibit mood shifts in response to both positive (rewarding) and negative (punishing) stimuli. One can examine these by analysing pertinent biomarkers, such as the levels of salivary cortisol (sCORT) and oxytocin (sOXT). In a study conducted by Moscovice et al. (2022), these were employed to investigate a cohort of 75 young pigs. The animals were categorised into multiple cohorts and exposed to various activities at different intervals, including the process of being separated from their mothers, experiencing short periods of social isolation without any social support, and engaging in playful behaviour. During the period from 28 to 65 days of age, we recorded the behavioural data of the individuals participating in the experiment. This included measuring the rates of agonism (fighting/rivalling), play, and affiliative (friendly) interactions. Subsequently, we collected saliva samples from the individuals for analysis. As anticipated, adverse social difficulties were linked to a significant rise in cortisol levels. The behavioural analysis validated the anticipated changes in social interactions when individuals gathered in groups, specifically a surge in conflict after the cessation of breastfeeding, succeeded by an upsurge in synchronised locomotor play during playful activities and frequent instances of friendly interactions. As per the findings of Moscovice et al. (2022), sCORT reactivity can indicate the strength of emotional reactions, with larger increases observed in response to challenges that involve higher levels of psychosocial stress. The findings also indicate that sOXT is an unreliable measure of emotional valence in pigs, requiring further research on the availability of social support or lack thereof.

Personality

Personality involves the recognition that animals, similar to humans, possess distinct psychological and behavioural characteristics that are unique to each specimen (Gosling, 2008). An examination of animal personality suggests a psychological connection between various species and humans. Animals are perceived as highly complex individuals. Personality, cognitive functions, and emotions collectively contribute to the understanding of animal behaviour and intelligence. Animals commonly exhibit personality traits. Several species of fish, birds, and mammals display lasting individual variations that can be organised into fundamental personality traits, some of which are similar to those observed in humans (Gosling, 2008). Humans have adopted a five-factor model of personality, which consists of openness, conscientiousness, extraversion, agreeableness, and neuroticism (McCrae and Costa, 2008). Research on animal personality reveals a different number of personality traits compared to humans. Pigs exhibit consistent behavioural and emotional characteristics that can be referred to as personality, such as consistent coping mechanisms, reaction patterns, temperament, and behaviour (Brown et al., 2009; Ijichi et al., 2013). Forkman et al. (1995) identified three fundamental personality traits in pigs: aggression, sociability, and exploration. These profiles exhibit strong similarities to those found in other animal species, and they also imitate human characteristics such as agreeableness, extraversion, and openness. Pigs possess enduring individual behavioural traits that reflect their nuanced personalities.

Summary

Pigs exhibit a diverse array of social behaviours, possess complex cognitive capabilities, and demonstrate a notable level of intelligence, which can be likened to that of primates in certain respects. The processing of stimuli through their sophisticated sensory systems is crucial in the acquisition and retention of knowledge and recollection. Pigs possess both short-term and long-term memory capabilities. By engaging in locomotor play, these mammals exhibit social interaction, exploration, and emotional development. Pigs possess the cognitive ability to acquire knowledge from previous encounters, differentiate between various individuals, including those within their own species and those belonging to other species. They utilise

spatial data and engage in competition with one another. They possess the ability to adopt a perspective, or in other words the viewpoint of another individual. These animals' capacity to perceive the passage of time through episodic memory is not well-defined. Pigs are believed to possess a certain degree of self-awareness, placing them among highly intelligent animals. Further research and observations are necessary to consider the unique characteristics of the species and gain a comprehensive understanding of the cognitive abilities of pigs.

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Approved for publication: 19 November 2023