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The Theoretical Application and Comparison of the Olfactory Sensory Organs in Swine vs Canines for Accelerant and Explosives Detection

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Swine may be able to work alongside scent detection canines, or replace them completely, in the scent detection field. Miniature pigs are the focus of this study since their larger counterparts can cause damage to potential evidence and to the scene itself. Ignitable Liquid Residues (ILRs) are searched for in post-fire conditions, and unconsumed explosives are searched for in major transportation hubs. Swine have more functional olfactory genes and less pseudogenes than humans, canines, and mice. Swine also have a highly functioning and exceedingly organized olfactory system. Swine are social creatures, which allows them to bond with a distinct handler. Their memorization skills show they can follow basic commands and learn tasks quickly. Swine can be trained in much the same way as canines are currently being trained for scent detection of accelerants and unconsumed explosives. Swine are receptive to play rewards, but work much harder for a sweet treat, like apples and other fruit. Much of the research done with swine was for barnyard/livestock application. Due to this, there was not enough pre-existing research to conclusively state whether or not swine have more superior odorant detection capabilities over canines in a working capacity, although both systems far surpass that of a human.

Keywords: Canine; Swine; Miniature Pigs; Scent detection; Odorant Detection; Target Odor; Accelerants; Explosives; Olfactory

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1.0 Introduction

This research evaluates the efficacy of using miniature pigs in the field to detect accelerants in post-fire conditions and unconsumed explosives. The focus is on miniature pigs since their larger counterparts could destroy the fire scene evidence and have already been shown to set off latent bombs (old war-mines detection) due to their size and weight (Warren 2013). Canines are currently used for these purposes and will serve as a comparative analysis to swine. Each species' olfactory sensory organs are analyzed to distinguish how each snout is used. This aids in understanding how each species smells and interprets the world around them with their "noses", and evaluates which snout may be more capable for this specific line of work.

Since the working canine and swine will have a human counterpart, the link between the animal and human is studied to determine the effect it has on the reliability of the team's results. The bond between the human and canine or swine could be a hindrance or a help. This research will focus on how little of a bond is needed between the two, and how much is too much. It is known that humans and canines share a bond, but that may be a hindrance for the working capacity of the animal. If swine can have a strong bond with their handler, but also separate work and play, they may be more suitable as a working animal since they may not aim solely to please their handler.

This research also identifies which approaches are the most widely accepted when training canines for this career, and if those same methods may be translated to prepare swine for this specialized profession. The importance of training, especially standardized training, spans both the theoretical and practical application of this research. If swine' noses are more adept at sniffing out the compounds, but they cannot be trained, then they will not be a better alternative to using canines; yet if they can be trained effectively and efficiently there is the potential they will work alongside canines, or replace them completely, in this line of work. Also, the inherent qualities and assets of canines and swine have been analyzed. Each species' alerting capabilities, their intelligence, and their agility is compared and contrasted to evaluate which species is the best fit for the job. Each of these abilities and attributes is significant for the research since it determines how competent each animal is at completing the task set forth for them.

1.1 Importance

This research is important for advancing the field of fire and explosives investigation. Research has been done on the efficacy of accelerant detection canines (ADC's) since the early 1990's, but were not adopted into NFPA 921: Guide for Fire and Explosion Investigations or NFPA 1033: Standard for Professional Qualifications for Fire Investigators until 1998 (ATF, 2016). ADC's were originally called Ignitable Liquid Detection Canine Teams and were listed as a special tool by these documents (NFPA 1033). Although research had been done, canine detection teams were not an accepted practice until they were published in the 1998 editions of both NFPA 921 and NFPA 1033. Detection canines now have their own sections in NFPA 921 and NFPA 1033, and advancements in research has followed along with changing standards.

It is common knowledge that canines can effectively be employed for scent detection in cases involving drugs, missing persons, cadavers, ignitable liquid residue, and explosives. ADC's have been trained since 1986 by the Bureau of Alcohol, Tobacco, and Firearms (ATF) for state and local law enforcement and fire departments (ATF, 2016). The ATF has been training Explosive Detection Canines since the early 1990's, and offered training to the federal, state, and local law enforcement agencies in 1998 (ATF, 2016). Swine have also been employed to use their noses, mostly to search for latent explosives (Warren, 2013) and truffles. The samples alerted on by the animal are then sent to a laboratory for chemical testing to validate the results of the search in order for the samples to be used as evidence in court. The Canine Accelerant Detection Association (CADA) and the National Fire Protection Association (NFPA 921) states that any canine alert not confirmed by laboratory analysis should not be considered validated. This paper does not contest that further analysis is necessary since the use of a combined system, chemical (lab) and biological (animal), is the best way to obtain accurate results (Furton & Harper, 2004).

No animal or instrument will be able to pinpoint a precise sample 100% of the time, but canines and swine are better equipped for naturally locating accelerants and explosives than humans or technology (Zubedat, 2014). Instrumental training does not rival the instincts of animals whose sense of smell has aided them in survival. Training swine to use their intelligence and olfactory organs to locate proper samples can increase the accuracy of sample and device detection in the field. The use of swine may improve the quality of samples collected, which in turn, may provide a more definitive and timely laboratory analysis. The improvement of sample quality may mean the decrease in needed samples, resulting in the reduction of cost for the laboratory, a reduction of time on scene for the investigator, and a reduction of work by the lab technician. This would allow for results to be returned to the investigator promptly ensuring cases to be processed in a more rapid manner. It is important to remember it is not the job of the animal to confirm ‘malicious intent’ or ‘arson’, but rather to find samples to send to the laboratory. It is the role of the investigator to determine origin and cause.

2.0 Olfactory

When training a service animal, it is imperative to understand how the systems being implemented work. In this profession, the olfactory system is the main anatomical element being used. With knowledge of how the olfactory system works, one may then train and use it to the utmost degree. This section focuses on the olfactory system—its components, how it works, and then will highlight the olfactory differences between canines and swine. First, the research will provide an overview of the mammalian olfactory system.

2.1 Mammalian Olfactory

The mammalian olfactory system is complex and varies from mammal to mammal, though each system shares similar traits. The purpose of the olfactory system is to identify the odor, discriminate it from similar odors, recall information that has already been learned about the odor's significance, and incorporate any new information that may accompany the presentation of the odor (Illig & Wilson, 2014).

The olfactory system (OS) in mammals is comprised of multiple parts within the nose and brain. The olfactory cortex is any region of the brain that receives information from the OS, and the olfactory bulb is the target for incoming information from olfactory sensory neurons (Illig & Wilson, 2014). The olfactory bulb plays a key role in the perception of odor quality of odorants in the brain (Farbiszewski, 2013). The vomeronasal organ is a patch of chemoreceptors in the main nasal chamber of the OS used to detect heavy moisture-borne odor particles (Zug, 2014). The olfactory epithelium is covered in a thin sheet of mucus where the odorants dissolve and bind to olfactory receptors where they are then transmitted to the olfactory bulb, which sends signals to the brain (Dorman, 2014). There is a main portion to the OS that deals with the environment around the mammal, and the vomeronasal portion which perceives pheromones (Farbiszewski & Kranc, 2013).

Odor information is integrated with other sensory cues, learned associations, and internal motivational states to generate a meaningful response to the odor (Illig & Wilson, 2014), which means that a certain smell can elicit a certain learned response. Each olfactory sensory neuron selects one or only a few odor receptor genes, which are widely dispersed and intermingled with other subtypes, creating a mosaic of sensory neurons expressing different odor receptor proteins (Mori & Yoshihara, 1994). This means odor information received by odor receptor proteins expressed in a certain zone of the epithelium may be transmitted selectively to the target neurons in the corresponding zone of the olfactory bulb (Mori & Yoshihara, 1994). The molecular receptive range of an olfactory bulb neuron is the range of odor molecules that either excite or inhibit the neuron (Mori & Yoshihara, 1994). This means the odors and odor compounds to train canines and swine with are the ones that excite the olfactory bulb neurons. Giving a positive response to the animal when it has correctly identified an accelerant or explosive will teach it that the neurons being excited when sniffing the material is what is expected of them. The merging of the receptor codes of two odorants provides novel combinations of receptor inputs that stimulate neurons beyond those activated by single odorants (Farbiszewski, 2013). It is to be noted that the length and/or structure of the hydrocarbon chain play an important role in response selectivity of olfactory bulb neurons (Mori & Yoshihara, 1994). This suggests similarly structured molecules can excite the olfactory neurons and be recalled more quickly than those molecules that inhibit the neurons. Furthermore, it was found by Mori and Yoshihara that odor molecules with a relatively long hydrocarbon side chains activate the olfactory cells much more than those molecules with shorter side chains (1994). It should also be emphasized that a slight change in the structure of the odorant can dramatically alter its perceived odor (Farbiszewski, 2013). This suggests that certain common fuels which have varying additives, such as gasoline, should be collected from a variety of sources (differing gas stations) so that canines and swine can positively recognize a wide range of chemical structures with more ease.

2.2 Canine Olfactory Anatomy and Odor Detection

Like most mammals, canine snouts are moist. This causes the odor particles to be broken down, permitting them to come in contact with the olfactory receptor cells. Canines use sniffing to detect odors. Sniffing is actually a disruption in the normal breathing pattern and is accomplished through a series of short, rapid inhalations and exhalations (Correa, 2011). A canine's snout is basically comprised of two parts – the nostrils for inhaling and the nasal cavity.

The canine's snout has some special features which help in odor detection. Humans have simple noses (microsmatic), while other mammals have more complex noses that support highly evolved olfaction (macrosmatic), which is due to differences in airflow patterns attributed to variations in the shape of nasal turbinates (Dorman, 2014). A canine's nose is shaped differently from a human's nose which allows significantly more airflow to pass directly over the olfactory receptors when compared to humans (Furton & Harper, 2004). Canines also possess larger olfactory tracts and bulbs compared to humans, with as many as 50 times more olfactory cells (Furton & Harper, 2004). In canines the olfactory bulb functions as a filter to background odors, which enhances the transmission of selected odors to the olfactory cortex, discriminates among odors, and enriches the sensitivity of odor detection (Jia, et al., 2014). The olfactory epithelium in a human is 10 cm^2 whereas a canine's is 170 cm^2 (Lippi & Cervellin, 2012). Olfactory receptor cells in a canine's nose extend throughout the entire layer of specialized olfactory epithelium found on the ethmo-turbinate bones (scrolled spongy bone in nasal passages) in the nasal cavity, and the olfactory portion of the nasal mucus membrane, which contains a rich supply of olfactory nerves connected to the highly developed olfactory lobe in the canine's brain (Correa, 2011). A bony subethmoidal shelf forces air into the olfactory epithelium and is located below the ethmo-turbinate bones, creating a nasal pocket that protects the odors from being washed out from exhalation (Correa, 2011). Correa states the nasal pocket permits unidentified odor molecules to accumulate and react with olfactory receptors which then generates nerve impulses in the canine's brain, allowing the canine to follow a scent trail leading to the unrecognized odor so the canine may identify the odor (2011). Once identified, the canine can recognize and recall the odor when presented with it again.

2.3 Swine Olfactory Anatomy and Odor Detection

Swine have elongated snouts that are specialized for rooting around in the dirt and mud. The supporting system for the outside nose houses the superficial portion, which includes the muscle and connective tissue, and the cartilaginous portion that controls the deep fibers of the nasolabial muscle (Soucek, Briet, Koning, & Liebich, 1999). According to the same study, the observed cartilaginous connection between the ventral lateral nose and the vomeronasal suggests another transport mechanism for odors. The olfactory areas in in swine are large and well organized, and the olfactory bulb has a superficial, thick olfactory nerve layer which contains the incoming axons of the olfactory sensory neurons that reside in the olfactory mucosa of the nasal cavity (Brunjes, Feldman, & Osterberg, 2016). This layer is very deep, suggesting swine have both a large number and diverse kinds of olfactory sensory neurons (Brunjes, Feldman, & Osterberg, 2016). Swine have been found to have the largest repertoire of functional olfactory receptor genes (Ahn et al., 2012), suggesting that when compared to other species, swine may have a more sophisticated system to sense smell and may be able to distinguish more diverse odorants (Nguyen et al., 2012).

Although swine brains are smaller than human brains when compared to total body weight, the olfactory bulb in swine accounts for nearly 7% of brain size, whereas in humans it accounts for only about 0.01% (Brunjes, Feldman, & Osterberg, 2016). The swine olfactory gene repertoire comprises of 17 families and 349 subfamilies and is the largest amongst mammals with 1,113 functional genes, whereas a canine has 872 functional genes, respectively (Nguyen et al., 2012). It has been discovered that 171 of the 212 swine-specific olfactory receptor genes are functional, showing that swine contain the largest amount of unique olfactory receptor genes organized in clusters, with swine having 61 clusters, mice having 39 clusters, canines having 19 clusters, and humans having 4 clusters of olfactory receptors (Nguyen et al., 2012). Swine have the lowest fraction of pseudogenes (a section of a chromosome that is an imperfect copy of a functional gene) within the olfactory receptor sequences at 14% (Ahn et al., 2012). The pyramidal cells (primary excitation neurons of the prefrontal cortex in mammals) in swine have 50% more dendritic branches and twice the total dendritic length as those found in the mouse (Brunjes, Feldman, & Osterberg, 2016). This suggests that swine are more evolutionary superior in regards to olfactory systems of mammals that have been studied (mice, canines, swine, and humans). Also, porcine genes involved in sensory perception, immunity, and host defense were among the most rapidly evolving (Ahn et al., 2012), signifying the prowess of not only the olfactory system in swine, but also their immune system.

2.4 Controversies to Using Animals

One of the controversies to using animals in a post-fire environment for accelerant detection is what the animal is smelling may have negative effects on their health. Dorman states the health risks of inhaled nasal toxicants can include chemically induced nasal lesions, sensory irritation, olfactory nerve toxicity, nasal immunopathology, and carcinogens in both humans and animals (2014). Dorman then goes on to state that the olfactory mucus contains various protective factors, such as immunoglobulins (antibodies), albumin (a protein), and lysozymes (enzymes that fight bacteria), which are thought to serve as a barrier against invasion of microorganisms and chemical toxicity (2014).

The other misunderstanding also deals with the loss of smell, especially specialized odor detection, due to pollutants, old age, and excessive use. Stem cells, or basal cells, regenerate tissues in the nose. Olfactory receptor neurons have a lifetime of 2-4 weeks (Dorman, 2014). In a 1994 study done by Mori and Yoshihara, it was found that in adult animals, the olfactory sensory neurons are continually generated from basal cells in the deeper layer of the olfactory epithelium, and despite continuous turnover of the neurons, the olfactory system keeps the integrity for the discrimination of odor molecules and olfactory perception. The new neuron contains the specific odor proteins of the neuron it replaces, which allows for a seamless transition from old to new. Farbiszewski (2013) states that the four leading causes of smell disorders are 1) trauma, 2) viral infections, 3) nasal causes such as sinusitis or nasal polyps, and

4) smell disorders associated with aging or neurological illnesses. It is uncommon for olfactory impairment cases to be caused by environmental pollutants; genetic defects, traumatic brain injuries, respiratory tract infections, and lesions in the central olfactory pathways (Dorman, 2014) are much more common causes for the loss/change of smell, permanently or temporarily, in humans. Further research needs to be conducted concerning loss of smell in animals, but it can be inferred that terrestrial mammals would share the same common factors for loss of smell.

3.0 Human-Animal Interface

Canines and swine were domesticated for different purposes. Canines were domesticated for companionship, sport/hunting purposes and protection, whereas swine were domesticated for meat (Nawroth, Ebersbach, & von Borell, 2013). During the process of domestication, canines evolved to meet many functional and emotional needs of humans (Roberts, McGreevy, & Valenzuela, 2010). Because of this, canines have been studied significantly more than swine in human-animal interactions, with much of it being common knowledge now. This section focuses on the evolution of human interactions with swine from the day they are born to the point they are working alongside humans. The canine portion will focus mainly on the handler-canine working relationship.

3.1 Human-Swine Interactions

Swine started becoming domesticated more than 9000 years ago (Nawroth, Ebersbach & von Borell, 2013) and more recently have been studied for a myriad of new purposes (medical, companionship, working animals), and thus, so has their relationship with humans. Handling studies indicate that swine learn to associate handler's presence with the animal's perceptions of the consequences of the handling bouts whether they be negative or positive (Muns, Rault & Hemsworth, 2015). This can greatly affect whether the swine perceives humans as a threat or not. The relationship that an animal has with its human counterpart is intimately related to the animal's welfare (Branjon et al., 2015) and an animal's fear of people can substantially reduce the animal's productivity and welfare (Koba & Tanida, 2001). Negative interactions by people can cause swine to become highly fearful of humans, and through stress, can cause impaired welfare and productivity (Muns, Rault & Hemsworth, 2015). Piglets exposed to rough handling or negative experiences with humans will learn to avoid the handler and other humans (Branjon et al., 2015). Less stress on the animal also means less stress for the human counterpart (Beaver, 2016).

Positive interactions from humans, on the other hand, can reduce the stress of swine when in the presence of people. Positive handling increases growth, reproduction, and feed conversion efficiency while reducing sustained elevations in basal free cortisol concentrations and/or an enlargement of the adrenal glands (Muns, Rault & Hemsworth, 2015). It has also been shown that increased positive human contact will lower brain beta endorphin levels and heart rate, both of which are indicators of stress (Beaver, 2016). Early gentle contact with people enhances approach behavior, and it is suggested that a straight-standing human is more threatening for swine than a handler stooping down (Branjon et al., 2015). A previous positive socialization to humans decreases the flight response and increases the motivation to approach the handler later in life, facilitating the development of a human-swine relationship (Branjon et al., 2015). Gently rubbing behind the ears and talking softly to [the swine] are effective calming techniques (Beaver, 2016) for both young and adult swine. It has also been observed that swine fed in the presence of humans and positively handled were less fearful of people, which provides evidence of positive conditioning through feeding (Muns, Rault & Hemsworth, 2015). Some argue that feeding may be the key for tameness, but others state feeding is not sufficient for the development of an affinity with a caregiver (Branjon et al., 2015), but rather force the swine to just associate humans with the provision of food (Muns, Rault & Hemsworth, 2015). Human presence itself is sufficient to attract piglets and they will actively interact with the handler, possibly because the human is perceived as a potential play partner/entertaining object (Branjon et al., 2015). A long-term positive human-swine relationship may be established through positive handling, leading to a positive perception of all humans (Branjon et al., 2015).

3.2 Human-Swine Working Parameters

Piglets have the natural propensity to interact with humans and they possess a remarkable adaptability to human behavior, openly showing frustration if the handler systematically refuses contact by pushing them away (Branjon et al., 2015). Swine show a tendency to approach attentive humans and show a significant preference for the person who looks at them (Narwroth, Ebersbach & von Burell, 2013). This want to be near to, and interact with, people show that well socialized swine can be a beneficial working counterpart to a person. Koba and Tanida (2001) discovered that the behavioral responses of swine to one handler are likely to extend to other humans as well. Swine can discriminate between people based solely on clothing color after several exposures (Koba & Tanida, 2001) and may learn to associate clothing color with a positive or negative experience. Miniature pigs are able to discriminate between a familiar and unfamiliar person based on visual, auditory, and/or olfactory cues, and it is suggested that olfactory cues and visual characteristics, such as body size and face of the person, are utilized by swine as discriminate stimuli (Koba & Tanida, 2001). Therefore, it can be deduced that swine are able to form a bond with a certain person and recognize others. Increasing the distance from a person and decreasing the light intensity (dimming the lights), as well as covering the upper body/face can make it more difficult for a swine to correctly identify a certain person, but increasing the body size (height and/or weight) made it easier for swine to discriminate between different people (Koba & Tanida, 2001). An unfamiliar handler may be perceived as potentially threatening (Branjon et al., 2015) especially if the swine is approached from behind, since swine have a relatively large blind spot behind them and their anatomy makes it difficult for them to look back (Beaver, 2016). Consistency is key when more than one handler is present. Changing handler action, inconsistent methods between handlers, and unneeded stimuli will make it more difficult for swine to learn the preferred task, but consistency in handler-to-handler technique, rate, timing, and angle of approach will condition the animal about what to expect next (Beaver, 2016). This will reduce the stress on the handler(s) and animals, as well as allow the swine to learn in an enriching environment.

3.3 Human-Canine Working Parameters

Canines, like swine, work best when socialized with humans as well as other animals. Poor socialization can lead to fear of humans or their environment (Wolters, 1995), which can cause difficulties with training or the inability to work effectively in the detection field. Socialization makes the canine bond to a person allowing it to become more trainable (Wolters, 1995). Another important factor in a young pup's life is "environment enrichment" and it should take place between the fifth and tenth week, since after the tenth week a pup will show fear in unfamiliar surroundings and stressful situations (Wolters, 1995). It is important to let the puppy explore and learn to give the pup a sense of mastery and control over his environment, which gives him or her a sense of confidence by avoiding threatening or stressful experiences when young (Wolters, 1995). It is encouraged to create a kennel to be a safe space for the canine, and when in there, he or she should not be disturbed (Wolters, 1995). This gives the canine a safe space to go to when it feels threatened, stressed, tired, or feels the need to be alone. The strongest bond will be established between the handler and canine between the seventh and twelfth week that the canine is alive (Wolters, 1995).

The handler-canine interaction is subjected to the handler's skills and the bond they share, with the canine's behavior being affected by the handler's personality (Zubedat et al., 2014). It has been found that a single canine-single handler team is the ideal system for the optimal detection of explosives since changing handlers resulted in lower percentages of correct detection (Zubedat et al., 2014). A specific canine-handler matching is beneficial to form an optimal 'canine-handler interface' which can be affected by the behavior of the canine as well as the affective (stress) and cognitive (attention) traits of the handler (Zubedat et al., 2014). The stress of the handler can be irrelevant to the task (external stress) or relevant to the task (internal stress), and can cause many different effects on the handler-canine interface and eventually on the performance of the canine during a scent detection task (Zubedat et al., 2014). Well-socialized canines, if allowed to vegetate in a kennel can actually regress through boredom, depression, and a lack of social interaction will lead to a decrease in their performance and bond with their handler, as well as sapping their motivation to work (Wolters, 1995). It is important to minimize stress on the canine while in the puppy stages and during the scent-detection task, and to socialize them with other animals, people, and differing terrain/environments.

4.0 Training Methods

This section combines the olfactory and behavior aspects of canines and swine, and introduces extrinsic environmental factors into implementing each species for a detection career. The animal will have to be able to distinguish the chemicals in a variety of physical states of matter, i.e. vapors (chemicals in air), solutes (chemicals in water), and residues (chemicals in soil) (Phelan, 2002), as well as differentiate between the explosive materials/residue and the container that may house the device. In order for the animals to succeed at this specialized task, proper training is a must. There are many ways to train service animals, but an all-encompassing approach works best.

4.1 Overview of Training- Accepted Practices and Methods

Training is based on a desired behavior, in this case odor detection, which brings a desired response, and then a reward (food or play) is given (FEMA, 2015). The basic principles for training an animal are as follows: 1) Show what the command means, 2) Embed the command through repetition, and 3) Stop giving praise once the command has been learned (Wolters, 1995). The first step lets the animal know what is expected and the second step reinforces what the handler wants the animal to do until it is second nature. Once the command is learned, it is important to stop giving rewards (play) so that the animal does the desired task for the sake of work, rather than to play. If the animal works for food, food must be given once the task has been completed. Food based training can be controversial. The accelerant detection animal does not receive any food unless it is earned through rigorous daily testing or while at an investigation scene (FEMA, 2015). The entirety of this training method is based on food as a reward, but most think that food should be inherent. If the animal is fed a bowl of food by someone other than the handler without thorough training/work first, their training could be compromised (FEMA, 2015). A treat reward system may work, but that could also lead to obesity. Play reward, on the other hand, is less controversial. The animal would receive a toy for a certain amount of time for doing well during training and/or an investigation. Praise is given for each type of rewarding system in addition to either food or play.

There are two main types of searches – free search and directed search. Each of these can implement the use of a leash, but that is based on the trainer or handler’s preference. A directed search is one in which the handler steers the canine to a specific area and a free search is where the canine sniffs randomly (FEMA, 2015).

The handler also needs proper training before entering this line of work. Effective handlers for accelerant detection animals need working knowledge of how to investigate post-fire conditions for origin determination and cause analysis. They may be a law enforcement officer or someone who has been exclusively trained in fire scene analysis. Most canines are trained in accelerant detection before they meet their handlers, but then must learn how to follow their handler’s commands (FEMA, 2015). The team will then go through a certification processes before working in the field. Some of the certification processes include the ATF, Fire K9, State Farm, or Scientific Working Group on Dog and Orthogonal Detector Guidelines (FEMA, 2015).

4.2 Canine Training and Alerting

ADCs serve two very important functions: 1) To help locate trace evidence of ignitable liquids and secure samples with a higher probability of a positive laboratory confirmation, and 2) To help eliminate the presence of ignitable liquids as a potential fuel source in the area of origin (CADA, 2012). These two tasks may sound completely contradictory, but they are one and the same. If the canine does not alert within the scene, there is the possibility accelerants were not used to start that particular fire, but if the ADC does alert, it is imperative to send the collected sample(s) to a laboratory for further testing. Training the canine team to re-check samples after they have been collected in sample containers to determine if the sample does contain residual odors (Tindall & Lothridge, 1995) is a good habit to develop since it moves the sample away from distractors. This re-checking process can reduce the number of samples sent to the lab and increase the number of positive results. It is important for the fire investigator and handler to keep in mind that an alert from an ADC is not synonymous with 'arson' or 'malicious intent' (Furton & Harper, 2004) since there are numerous flammable and combustible liquids that are incidental to most aspects of life (Tindall & Lothridge, 1995).

Even though canines can recognize odors and improve at their jobs over time, the initial training can take four to six months when done properly (Vos, 2008). A basic training framework includes the imprinting of the odors the canine is meant to detect, employing representative distractors or odors likely to be encountered in the field to which the canine should not alert, and providing consistent reinforcement to ensure reliable results (Furton & Harper, 2004), but one of the first, and most basic things a canine must learn is that commands are to be followed, not considered (Wolters, 1995). Distractor odors during training for explosives can be soil, metal, tea bags, packaging materials (Lazarowski & Dorman, 2014) with partially burnt materials like foam, wood, and plastics used during accelerant detection training. The most common substance for accelerant detection training is 50% evaporated gasoline (Tindall & Lothridge, 1995), and Potassium Chlorate (Lazarowski & Dorman, 2014) is common in explosives detection training. The ATF trains canines on five basic explosive groups, which they estimate are in 19,000 different formulas that the canines are then able to alert on (ATF, 2016). To pass the certification course, the canines must alert on twenty different explosive odors, two of which they are not exposed to during training (ATF, 2016).

Canines have the natural ability to learn on two levels: conscious and unconsciously. Conscious learning is when the canine knows that he or she is learning. This is satisfied while imprinting odors by letting the canine sniff the material, placing it in a container and having him or her discover which one of the containers the target odor is in. Unconscious learning is when the canine is put into a situation repeatedly and is only able to get experience by being in that place or situation until it becomes natural for him or her (Wolters, 1995). Some examples are distance training (how far the canine may go on or off leash during free sniff searches), which side of the handler the canine heels to, or learning the ‘start’ command which lets the canine know the odor detection task is at hand. Inadvertent unconscious learning during training can also occur through the human-animal interface. The trust of canines on human cues has been shown to prevail over both olfactory and visual indications, so the canine may respond to unintentional human cues aimed at a desired target scent (Zubedat et al., 2014) during training. Handler error was observed to mislead the canine into false identification by forcing the canine to obey rather than detecting based on previous learning processes and training procedures (Zubedat et al., 2014). On scene, if a handler is preoccupied with a certain area, the canine may continue to go to that area even if there are no accelerant or explosive residues. This behavior leads to false-positives (an alert where there is nothing to alert on). To avoid unintentional cueing during training, the handler should avoid eye contact and maintain a neutral body position (Lazarowski & Dorman, 2014), which, in the field, could be more difficult if the canine is trained to work on a leash. False positives also occur if the canine was not trained on a wide variety of odors. A study by Lazarowski and Dorman in 2014 concludes that exclusively training canines with a standard amount of a single substance was not sufficient for the canine to create a reliable generalization when the target substance was binary (a mixture), but also found that the components of the mixture do not need to be physically mixed.

Handlers are also trained to keep a close eye on the search area and their canine to watch for potential hazards (Vos, 2008). In addition, handlers are trained to verbally encourage their canines during the search, praise them once the task is completed, and show the canine his or her full attention, otherwise the canine gets distracted and tired easily, and can only work for as little as two hours (Vos, 2008). Canines can be trained to continuously preform effectively for 90-120 minutes, but in extreme conditions will require a rest stop after 40 minutes of searching (Furton & Harper, 2004).

Canines can be trained to alert in many different ways. The type of alert canine gives can be based on handler/trainer preference or what the canine is naturally inclined to do. Some examples include sitting, lying, pointing, digging, chewing (Tindall & Lothridge, 1995), pawing, barking, howling, growling, whining, or a combination of any of those. Digging and chewing can be undesirable alerting actions since they can disturb the scene and destroy evidence. Alerting a certain way can be reinforced with praise and food or play reward.

4.3 Swine Training and Alerting

There is very little research pertaining to the training of swine in conditions other than livestock handling, which may be attributed to their domestication. Although much is in the livestock handling realm, much of the research and training practices can be transferred over for a scent detection career. It has been found that swine learn primarily by trial and error, with an associated reinforcement (Beaver, 2016). A stimulus (detectable change) is needed for a response (resulting behavior) to be detected. Learning happens when a consistently applied stimulus results in predictable behavior (Beaver, 2016).

Swine, like canines, have two primary ways of learning a new task. Swine can be exposed to either operant or classical conditioning to achieve a desired result, and they learn by the association of events and outcomes (Beaver, 2016). Classical conditioning is much like habituation; the animal gets used to sounds or a signal and gets prepared for a certain task or event to happen. Operant conditioning requires the swine to be active in the learning process. Classical conditioning means the swine has no control over the outcome and operant conditioning gives the swine some control of the outcome (Beaver, 2016). It is imperative to teach young swine the correct responses before they have the ability to learn undesired ones, and conditioning, when done correctly, can take very little time out of the working day (Beaver, 2016). Repetition and reinforcement cause the swine to give their handler the desired response. When training, it is important to remember to stay consistent and provide immediate reinforcement, which could be positive (instantaneous reward, like fruit) or negative (relief from a stimulus) (Beaver, 2016). As seen with canines, positive reinforcement seems to be best suited for the scent detection career. The swine must have a habituation period to their new surrounding before the training starts. A habituation period of about 5 days is normal (Nawroth, Ebersbach & von Borell, 2013).

Swine are curious by nature and will stop to look at new things, and handlers find they have a remarkable memory (Beaver 2016), indicating the want to learn about their surroundings and the ability memorize them. In another study, it was suggested that swine not only remember the ‘what’ and ‘where’, but also the ‘when’ of the events (Nawroth, Ebersbach & von Borell, 2013). This means they can learn a step-by-step process (i.e. Step A will come before Step B which comes before Step C, etc.). Swine have been trained to listen to a voice and follow it for a reward of a raisin, and then to go back to a waiting area after receiving the reward (Koba & Tanida, 2001). That study shows the ability of the swine to learn a “come” and “stay” command and suggest that they would be able to learn other auditory commands. It has been found that swine are able to use head cues to discriminate (Nawroth, Ebersbach & von Borell, 2013) which means they may be able to learn to work off the head cues of their handlers, or they may also be prone to inadvertent positives while working.

Another technique used in learning is to gradually increase the difficulty of certain tasks. Just as with canines, it is important to imprint the smell onto the swine. Once the swine recognizes the smell, it may be hidden so they search for the target odor. Adding more places where the target odor may be hidden and introducing distractor odors is how the swine will be prepared for in the field scent detection operations. Environmental enrichment is important to swine as well. Building a ramp and placing a treat at the top will encourage the swine to explore while simultaneously adjusting the swine to differing elevations in a normal fashion (Beaver, 2016). It is best to reward the swine immediately after the desired response (going up the ramp, detecting the correct odor, alerting) to encourage the swine to repeat that response, and it has been found that a small amount of a sweet treat is a high-value reward (Beaver, 2016). Fresh vegetables, fresh and dried fruit, some cereals and unsalted peanuts are healthy treats for swine (Beaver, 2016).

The alerting capabilities of swine are varied, so the handler must keep a close eye on their animal counterpart. Some known alerts include pointing, gazing, and touching the item with their snout, which were reinforced with an apple slice (Nawroth, Ebersbach & von Borell, 2013). Swine, like canines, enjoy play time. Play markers include vigorous head movements while standing, biting the handler’s boots, and chewing on the clothes of the handler (Branjon et al., 2015). These instinctual movements could be implemented as an alert tool and they suggest that swine will respond positively to a play reward on completion of a task. Since swine have shown the ability to respond to a handler’s voice and the want to make contact with the handler, it is important that the handler encourages the swine during the task and reinforces them through praise, either verbally or physically.

5.0 Discussion

The possibility of using miniature pigs for accelerant and explosives detection was investigated. The ability of the swine olfactory system, the ability to bond with humans, and their ability to be trained was compared against canines. Undisputedly it was found that canine and swine olfactory systems are much more advanced than humans, but there was not enough pre-existing research to conclusively state whether or not swine have more superior odorant detection capabilities over canines in a working capacity (Figure 1). This is due in part to the canine olfactory system being more studied, and in part due to the livestock/barnyard intensive research done solely on swine. Despite the paucity of research done on the olfactory system in swine, what had been done was useful. It has been discovered that swine have 1,113 functional genes, which is the highest of any mammal, and they have the lowest fraction of pseudogenes. This means they have the largest amount of specialized and functioning olfactory genes, with a small amount of the genes being innate. The olfactory cortex in swine is highly organized. Both of these lead to the conclusion of a superior olfactory system. In comparison, canines have 872 functional genes and a large olfactory tract. It is known that canine olfactory sensory organs are superior to humans, but now there is research suggesting swine have a superior olfactory system to canines (cite). Figure 1 illustrates a Venn diagram comparing some of the differences and similarities between swine and canine.

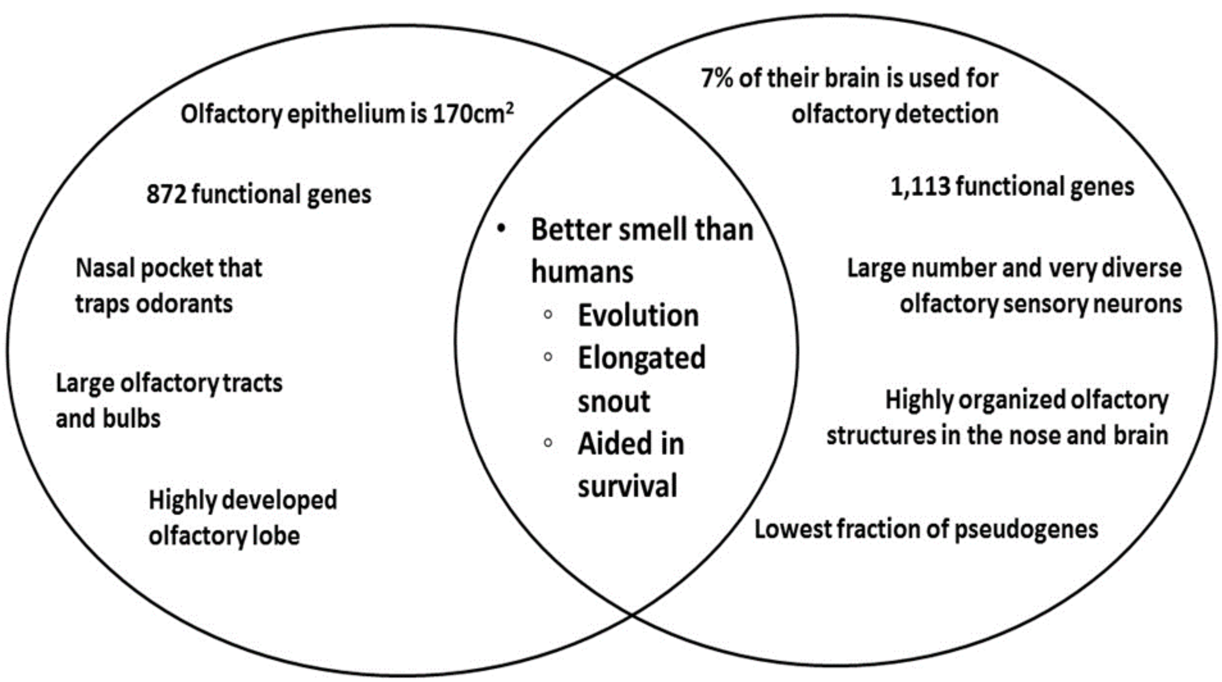

Figure 1*:* Venn diagram comparing canine (left) and swine (right) olfactory anatomy and odor detection

Canines are known as man's best friend since they bond so well with humans. This can be attributed to evolution since they were domesticated for man's protection, to help man hunt, and for sport, which lead to benefits for the canine (e.g. shelter, steady food, protection). Swine, on the other hand, were domesticated for meat quality and were left in a paddock rather than being welcomed into the home. Once again, there was much more research with canines than there was for swine in regards to the ability to bond with humans. Swine are able to form a working relationship and a bond with humans. It has been found that contact with humans on the first day of life will allow them to habituate to humans more quickly, and will lessen the fear of being handled later in life. Swine have an episodic memory, meaning they can remember the "when" and "where" of events, and can associate a positive or negative influence based on the situation. This means if you mistreat a swine, they will remember it, just as they can remember a positive experience. They are able to distinguish between people, are curious by nature, and one study found they will get frustrated if the handler does not pay attention to them. Swine prefer attentive handlers and will work better with a human that pays attention to them. Positive handling (e.g. gentle strokes, soft voice) develop a better bond between human and swine, and reduce fear in stressful situations. It has been suggested that swine will learn to associate a handler with food if provision of food is the only contact a swine has with humans, but other studies suggest that food can strengthen and deepen the bond between the handler and swine. Positive handling and socialization with humans and other animals can reduce stress that can lead to a positive perception of all humans. Piglets have shown the inclination to interact with humans and possess a remarkable adaptability to human behavior. These factors strongly suggest that miniature pigs can work effectively alongside humans in stressful situations.

When training an animal for a scent detection career, the training must be all encompassing, meaning training should happen at all times of the day, in different weather conditions, in various terrains, and with distractions (people, other animals, distraction odors) in order to prepare them for work in the field. The overall framework of training is to imprint the target odor, choose a search and alerting method, and gradually increase the difficulty of the training sessions. The target odor should not be placed every run so the animal can learn that not detecting an odor on scene happens. Training also establishes which reward system should be used for the animal, which can include food, play, or treat. Canines can be, and are usually, trained with either food reward or play reward. Small sweet treats, such as fruit, have been shown effective to motivate swine to complete a task in livestock applications, which indicates they may work best with a treat system. Swine do respond to playing, but not as well as canines. Handlers must previously be trained in fire investigation, but should also undergo training with their animal counterpart. This allows a working bond and routine to be set for a particular human-animal team. Handlers must also be trained to identify hazards, aptly conduct the reward, and continue and advance the training of their animal counterpart. Swine have the ability to learn commands and are naturally curious about their environment. Their known alerting capabilities include pointing, gazing, and touching the item with their snout. The ability to be trained to follow commands, their natural propensity to explore their environment, and the ability to learn differing alerts strongly suggest that miniature pigs have the ability to be efficiently and effectively trained for a scent detection task.

6.0 Conclusion

The results indicate swine have the ability to work in the scent detection field alongside canines. Their inherent curiosity, intelligence, and memory allow for them to be trained and to remember their training. It has been suggested that verbal praise and a play or food reward will enforce the desired action, whether that be alerting, searching, or training. Swine have the ability to bond with humans and remember human contact on the first day of life. They can recall if the experience was positive or negative, and distinguish between handlers. As with canines, it is best if swine are trained and work solely with one handler. This consistency in training and work allows them to improve over time, rather than regress due to differences in the structure of the training and reward system. It is also important to remember it is not the job of the animal to determine the fire was set with malicious intent, and if the animal alerts, it is not indicative of arson since flammable and combustible liquids are common in most aspects of life.

7.0 Future Research

The future research that needs to be conducted spans many disciplines. Additional research is needed regarding the olfactory system in swine, with an emphasis on miniature pigs. Sensitivity versus selectivity needs to be researched with both canines and swine. Also, the causes the loss of smell need to be further studied in swine and canines. The memorization and recognition ability in miniature pigs need to be further evaluated, especially in a non-livestock setting.

Monitoring and evaluating needs to be conducted in a non-livestock setting. This work could take place in the handler's home to establish a baseline expectancy of the communication, playfulness, and personality of miniature swine in order to create a training schedule that is tailored to swine rather than canines. This in-home assessment could help determine at which age is appropriate to begin training swine for a scent detection career. The prime age to begin teaching canines scent detection is between the twelfth and sixteenth week of life, but in swine it has yet to be determined.

A practical comparison also needs to be drawn between swine and canines for detection tasks. This could be achieved by raising canine and swine in a training facility setting at the same time, training on the same schedule, and comparing them side by side. Food, play, and treat reward systems can then be evaluated to determine which reward system works best for swine, and this location could test the in-home theories of which age is best to begin training swine. This would create a setting for practical comparison between the two species, and also allow various methods to be tested at once.

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