INDIVIDUAL BEHAVIOR TYPES AND SOCIAL COHESION OF GROUP-HOUSED PIGS

By

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PUBLIC ABSTRACT

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In recent years, consumers have become more concerned about the welfare of our livestock animals. A major concern from consumers is how we house our gestating sows. Due to consumer demand, mandates from food companies, and legislation, producers have to transition their sows out of gestation crates and into group-housing systems by certain deadlines, many falling between 2020-2022. Group housing can improve pig welfare by allowing interaction with other pigs and the ability to perform more natural behaviors. Unfortunately, group housing can also compromise animal welfare. Pigs at other production stages, such as grow-finish, are housed in groups and are often housed with pigs of the same sex and of a similar weight to help producers better allocate resources. However, pigs are complex social animals, and when unfamiliar pigs are introduced, it can lead to high amounts of aggression as pigs establish a dominance hierarchy. This intense aggression can last up to 48 h with low levels of aggression seen in more stable social groups. These bouts of aggression can lead to injury and stress. In order to address this welfare concern, a better understanding of pig behavior and pig social dynamics is needed to allow producers to implement management techniques and incorporate positive social behaviors into their breeding programs. This research aimed to investigate the differences in personality in individual pigs and how traits of individuality and differences in social behavior affect levels of aggression. Results from this study suggest that personality traits have the potential to improve the management and welfare of pigs, that individual personality traits are related to aggression, and that certain affiliative behaviors can result in decreased or increased aggression.

ABSTRACT

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Group-housing of pigs can provide benefits for pig welfare, such as interaction with conspecifics and the ability to perform more natural behaviors. Unfortunately, group-housing also presents major welfare concerns. Pigs are often mixed at different production stages based on sex and weight in order to create uniform groups that allow for more efficient resource use by producers. Unfortunately, when unfamiliar pigs are introduced this causes intense aggression as pigs establish a social hierarchy. This increased aggression can persist for 24-48 h after a mixing event and can lead to injury, infection, and stress. Pigs are highly social animals, and as such, have individual differences in behavior and complex social relationships that need to be considered when addressing social aggression. The long-term goals of this project were to identify individual behavior types and understand the role of individual behavior types in social behavior in group-housed pigs. The specific objectives for this research were to understand the role of personality in the management and welfare of pigs through a comprehensive literature search, to identify individual behavior types in group-housed pigs using individual time budgets and behavior tests, and to explore measures of social cohesion in recently mixed pigs as they form a stable social group. Many studies have investigated the role of personality in the management of pigs but as a new field of study there are a number of issues that prevent the advancement of this field into behavioral management of livestock. Despite that, pig personality traits have been related to factors related to pig physiology, housing environment, social behavior, and cognition and therefore there is potential for producers to incorporate pig personality information into their breeding, care, and welfare. Individual pigs vary in their

overall behavior, therefore part of this research aimed to compare pig time budgets with duration of aggression at different time points. It was found that pig behavior varies immediately after mix and becomes more consistent at 6 wk after mixing. The amount of time pigs spend on non-aggressive behaviors was related to aggression, particularly time spent inactive and exploring. We also compared duration of aggression with production traits of growth rate, backfat thickness, and loin muscle area. Pigs that are more aggressive at mix and at 3 wk after had slower growth and smaller loin muscle area, suggesting that efforts to reduce aggression should be implemented not only after mixing, but in the weeks following to prevent negative consequences on production traits. One solution to address the issue of aggression is to breed for less aggressive pigs without inadvertently disrupting other behavior traits important in managing pigs. Behavior tests were used to assess traits of fearfulness and response to humans, and these measures were compared with lesion scores, a proxy measure of aggressiveness. Aggressiveness was related to pigs' responses in social and non-social challenges, suggesting there could be correlated suites of behaviors that should be considered when breeding for less aggressive pigs. Another important aspect to consider when addressing issues of aggression in group-housed pigs is their sociality. Social animals display a wide number of behaviors to maintain social bonds. Affiliative and agonistic behaviors were compared at 4 time points and revealed that certain affiliative behaviors are related to less aggression, suggesting potential for selection on positive social behaviors. Overall, the results of this research suggest that the role of individual behavior types in the social cohesion of group-housed pigs is important to consider. Future directions of this research will explore this idea in more depth and aim to guide pig producers on how to manage group-housed pigs in a way that not only reduces aggression but promotes positive social behaviors and good welfare.

I dedicate this dissertation to the animals
who give everything to benefit the health and welfare of humans.

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KEY TO ABBREVIATIONS

AGG = Aggression at mixing

AI = All combined nosing

B-mode = Brightness mode

BT = Backtest

cm = Centimeters

cm^2 = Centimeters squared

CT = Connecticut

DDT = Delay discounting task

ET = Emergence test

EXT = Extinction test

FC = Food competition test

FM = Food motivation test

h = Hour

HAT = Human approach test

HM = Handling – movement

HO = Handing – other

HOME = Activity/behavior in home pen

HSD = Honestly significant difference

ICC = Intraclass correlation coefficient

II = Extreme force nosing

kg = Kilogram

log = Logarithm

m = Meter

min = Minute

MI = Michigan

NI = Low/moderate nosing

NOT = Novel object test

NR = Novel rope test

ODT = Open door test

OFT = Open field test

Q.Q. = Quantile-quantile

RI = Resident-intruder test

RT = Restraint test

s = Seconds

SC = Social challenge test

SD = Social dependence test

SE = Standard error

SI = Social isolation test

SRUC = Scotland's Rural College

TT = Towel test

USA = United States of America

USDA = United States Department of Agriculture

wk = Week

CHAPTER 1: GENERAL INTRODUCTION

INTRODUCTION

Group housing in the swine industry

In the United States, there has been a recent increase in concern for the welfare of our meat animals, with consumers being more conscientious of welfare than they were five years ago (Ochs et al., 2018). Concern over animal welfare is influencing consumer purchasing decisions with some consumers opting for welfare-friendly products despite higher prices and increasing numbers of consumers opting to avoid animal proteins altogether (Janssen, et al., 2016; Clark et al., 2017). When surveyed regarding their concerns for the welfare of production animals, consumers most often are concerned about the 'naturalness' of the animal and how livestock management practices prohibit animals' abilities to exhibit natural behavior (Thorslund et al., 2017). However, consumers tend to lack the general understanding of animal ecology, behavior, and livestock management that would allow them to make informed decisions regarding animal welfare regulations and legislation (Ryan et al., 2015; Clark et al., 2017; Thorslund et al., 2017). Consequently, implementing consumer-driven regulations can sometimes cause other welfare concerns, raise food and production costs, and not translate in a willingness to pay for the product for all consumers (Tonsor et al., 2009a; Thorslund et al. 2017).

One of the major concerns from consumers is over restrictive housing, such as gestation crates for pregnant sows, and there is an ongoing push from consumers to remove sows from gestation crates and instead house them in groups in larger enclosures (Tonsor et al., 2009b; Thorslund et al.; 2017). In response to this pressure, the European Union, Canada, and New Zealand implemented legislative bans on gestation crates in 2013, 2014, and 2015 respectfully. Within the United States, ten states have passed legislation to phase out the use of gestation crates, with more legislative campaigns in other states to address this concern. Over 60 major food companies, including McDonalds, Smithfield, and Target, have made statements against the use of gestation crates, asking their producers to phase out this practice by certain deadlines, many falling between 2017 and 2022 (Tonsor et al., 2009a; Andrews, 2014).

Removing sows from gestation crates and placing them into group-housing systems addresses some of the consumers' concerns over the naturalness of the animal by providing increased space per pig, the opportunity to interact with other pigs, and allowing pigs to perform more natural behaviors (McGlone, 2013). Unfortunately, allowing social interactions among sows introduces a new welfare issue to the production environment that many consumers remain unaware of (Ryan et al., 2015). Pigs are aggressive towards unfamiliar conspecifics, which can lead to intense fighting and an increase in injuries in group-housing systems (McGlone, 2013). In these systems, pigs are housed based on weight and sex to create uniform pens that can be fed and managed in ways that maximize the efficiency of production, but this practice exacerbates the issue of social aggression (Turner et al., 2010). Aggression in group-housing systems is currently a major welfare issue in the swine industry that does not yet have a sustainable solution, largely due to producers' perception and lack of prioritization of the issue and their concerns on the economic viability of implementing and maintaining solutions (Camerlink & Turner, 2017; Peden et al., 2018).

The current change to group housing of gestating sows caused by consumer demand, along with ongoing welfare concerns in group housing systems used for pigs in other stages of production creates a need for research addressing issues of aggression and sociality. This research aims to address the issue of social aggression by investigating the role of animal personality in the social dynamics of group-housed pigs.

Social Behavior in Pigs

Pigs (*Sus scrofa*) are gregarious animals. Under natural conditions, sows live in matrilineal groups, with boars living solitarily outside of the breeding season (Pond & Mersmann, 2001). Within social groups, pigs form and maintain dominance hierarchies based on the competitive ability of individual pigs manifested primarily through aggressive and avoidance interactions between members of the social group (Meese & Ewbank, 1973; Jensen & Wood-Gush, 1984; Turner et al., 2010). Although pigs are naturally territorial, aggression between unfamiliar social groups has rarely been observed, suggesting that wild and feral pigs avoid interactions with unfamiliar animals to reduce conflict (Gabor et al., 1999; Turner et al., 2010).

In contrast to groups formed under natural conditions, domestic pigs housed under commercial conditions are often mixed with unfamiliar pigs causing intense aggression for 24-48 hours as the pigs establish a dominance hierarchy (Meese & Ewbank, 1973). Mixing occurs at different production phases based on age, weight, sex, and stage of gestation until they reach market weight or when gilts are retained as replacement breeding stock and moved into gestation crates (Camerlink & Turner, 2017). Therefore, pigs could be mixed into a new social group 2 to 5 times during their lifespan. This can lead to injuries, and infection and illness due to a lower immune response caused by stress, and, ultimately, higher rates of culling animals before they are considered profitable to the producer (Turner et al., 2010; Peden et al., 2018). Producers mix pigs to create uniform groups to maximize the efficiency of resources, but this practice increases and prolongs levels of aggression as pigs of similar competitive abilities are introduced into a pen with limited resources and space to escape or avoid others (Rushen, 1987; Turner et al., 2010). Thus, social aggression in group-housed pigs is a persistent and complex welfare concern.

Aggressive behaviors can include reciprocal aggression and non-reciprocal aggression in the forms of bites, full body presses, and head knocks, and can cause both acute and chronic stress and injuries (Greenwood et al., 2014). The most common injury seen in recently mixed pigs are skin lesions, shallow cuts on the surface of the body occurring as a result of bites from other pigs. Lesions vary between individual pigs according to their fighting strategy and are thought to be a reliable proxy for individual aggressive behavior at mixing (Turner et al., 2010; Greenwood et al., 2014). The number of lesions present on a pig is proportionately related to the amount of time spent in aggressive interactions, and the location of the lesions on the body indicates how the pig was involved. For example, lesions to the front of the body typically indicate pigs actively engaged in aggressive interactions, whilst lesions to the rear of the body are indicative of pigs retreating from aggressive interactions (Turner et al., 2009). Mixing aggression can also lead to lameness and other injuries or infections of wounds. Mixing unfamiliar pigs also causes stress, which could negatively impact immune function, growth, reproduction, and meat quality (Turner et al., 2013; Greenwood et al., 2014; Peden et al., 2018). One of most promising solutions currently includes genetic selection for pigs best suited for group housing (Peden et al., 2018), but as of now little is known about what an appropriate social phenotype might be for commercially group-housed pigs.

Studies that aim to address the welfare issues associated with mixing of unfamiliar pigs have primarily focused on investigating ways to reduce aggression. However, as highly social animals, pigs likely show a much broader range of social behaviors including behaviors that are meant to promote positive interactions. Some potential positive social behaviors in pigs include spatial integration, gentle nosing, and play but little is known about these behaviors and how they influence levels of aggression in group-housed pigs (Erhard et al., 1997; Turner et al., 2013; Camerlink et al., 2014). Learning more about the various ways in which pigs build strong social bonds is important for researchers and producers as it will allow us to manage pigs in a way that not only reduces negative interactions but promotes positive interactions. Understanding the role of positive social indicators could provide a way to identify stable and unstable social groups and could give producers the opportunity to use behavioral management techniques as needed to prevent loss and the ability to select for pigs that display positive social behaviors as well as selecting against negative behaviors.

Measures of spatial integration, the physical distance between conspecifics, have been suggested as a non-invasive way of assessing social cohesion in group-housed pigs. For example, pigs will lay physically closer to familiar pigs compared to unfamiliar pigs for at least the first 24 hours after mixing, or possibly not even fully spatially integrate until several months following a mixing event (Turner et al., 2013; Camerlink et al., 2014). The mix of behavior types within groups of pigs has been shown to influence the rate of spatial integration, with groups of pigs containing a higher number of aggressive individuals taking longer to integrate than groups with fewer numbers of aggressive individuals (Erhard et al., 1997). Measures of spatial integration may be a valid indicator of social stress as greater inter-pig distances have been related to higher activity levels, fewer feeding bouts and shorter feeding durations (Turner et al., 2013). Short inter-pig distances, particularly physical contact, have been used as a measure of preferential associations with results showing preferential associations among 97% of the pigs, but the contextual nature and long-term implications of the preferential associations have not been explored (Durrell et al., 2004).

Social nosing in pigs appears to be a means of recognition or indicator of affiliation among familiar pigs. However, studies exploring the meaning of gentle nosing and its relationship to other measures of social cohesion or production have yielded varying results (Camerlink et al., 2012; Camerlink & Turner, 2013; Camerlink et al., 2014). Nosing in pigs may be related to activity levels, body weight, and number of skin lesions after mixing, with pigs who nose less being less active, having fewer lesions, and being lighter in weight (Camerlink et al., 2014). It has also been shown that pigs that receive higher amounts of gentle nosing have a higher growth rate, but that receipt of nosing was not related to rank in dominance hierarchy, amounts of aggression received, or oral stereotypies such as tail biting (Camerlink et al., 2012; Camerlink & Turner, 2013).

Play is a behavior exhibited primarily by juvenile animals, thought to be important in the development of important physical and behavioral skills needed to survive as an adult (Martin et al., 2015). Play in animals typically includes social play, object play, and locomotor play (Ahloy-Dallaire et al., 2018). There are 5 characteristics that are used to describe play including: 1) not fully functional, 2) different from the adult behaviors they are similar to, 3) repetitive but not stereotypic, 4) reinforcing, 5) present in times of low stress (Ahloy-Dallaire et al., 2018). The presence of play is often considered an indicator of positive welfare in animals, with challenging or stressful situations decreasing the prevalence of play (Donaldson et al., 2002; Held & Špinka, 2011; Ahloy-Dallaire et al., 2018). However, play is also seen in humans and animals in poor affective states, possibly indicating that play can be a coping mechanism for individuals under stressful conditions and suggesting the presence of play should be interpreted cautiously (Ahloy-Dallaire et al., 2018). Pre-weaning environment and stressors influence the ontogeny and amount of play seen in piglets (Donaldson et al., 2002; Martin et al., 2015). In pigs, play occurs most frequently when piglets are 2 to 6 weeks old but can occur in any age of pig, with males and females playing at similar rates (Newberry et al., 1988). Assessing the onset and frequency of play in groups of recently mixed pigs and established groups of pigs could provide insight into social group cohesion, and the relationship between social aggression and the occurrence of play in group-housed pigs.

OBJECTIVES

The long-term goal of this project is to identify the individual behavior types exhibited by domestic pigs, and to explore the role of individual behavior types in social cohesion in pigs that have been recently mixed into a new social group. The specific objectives for this research are:

Objective 1: Understand the role of personality in the management and welfare of pigs through a comprehensive literature search.

Objective 2: Identify individual behavior types in group-housed pigs, using individual time budgets and behavior tests to develop a comprehensive behavior profile.

Objective 3: Explore measures of social cohesion in recently mixed pigs as they form a stable social group and identify factors that lead to successful and unsuccessful social group stability.

CHAPTER OVERVIEW

Chapter 2 focused on reviewing what is known about how personality influences the management and welfare of pigs. A total of 83 studies were systematically reviewed to provide insights into the current state of personality research in pigs, including what information we know now and constructive criticisms of how this area of study needs to improve.

The goal of Chapter 3 was to investigate behavior of recently mixed finisher barrows (castrated males) to gain an understanding of how group-housed pigs spend their time on a daily basis at multiple time points. Behaviors such as inactivity, movement, ingestion, social behavior, aggression, and exploration were recorded at multiple time points. These data were summarized to obtain a time budget. Pig time budgets were compared to social aggression and production parameters including growth rate, backfat thickness, and loin muscle area to investigate the relationships between these variables.

Chapter 4 explored the relationships between aggressiveness, fearfulness, and response to humans in finisher barrows. Lesion counts were used as a measure of aggressiveness, a novel object test was used to measure fearfulness, and a human approach and a handling test were used to measure response to humans. Responses in each situation were compared to better understand the relationship between these traits.

The objective of Chapter 5 was to assess the relationship between affiliative and agonistic behaviors. Pigs were video recorded at different time points, and the videos were observed for agonistic behaviors such as reciprocal fights, attacks, head knocks, and pressing, as well as for affiliative behaviors such as play, social nosing, and affiliative physical contact. The affiliative behaviors were compared to agonistic behaviors to better understand how pigs establish and maintain social relationships.

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CHAPTER 2: ANIMAL PERSONALITY IN THE MANAGEMENT AND WELFARE OF PIGS

O'Malley, C.I., Turner, S.P., D'Eath, R.B., Steibel, J.P.,
Bates, R.O., Ernst, C.W., & Siegford, J.M.

ABSTRACT

Personality is defined as individual behavioral differences that are consistent over time and across contexts, while personality traits are specific aspects that combine to make an individual's personality. Over the last 27 years, studies on pig personality have investigated links between personality traits and behavioral and physiological responses. The objective of this paper was to review the literature on personality studies in pigs. Eighty-three peer-reviewed research articles were included. The most common objective of these studies was to identify personality types in pigs by comparing their response across multiple situations. The relationship between personality traits and physiological responses was the next most common objective. Results were difficult to compare as there was little consistency in terminology or experimental design across studies. Only 24.1% of the studies reported reliability for measures used to assess personality traits and even fewer explicitly assessed validity. The backtest was the most common test (used in 67.5% of the studies), though it is unclear what specific personality trait is being measured. Classifying pigs as proactive or reactive personality types using the backtest was common, but the relationship between backtest results and other variables are inconsistent. The human approach, novel object, and food competition tests were also popular methods for measuring personality traits. Exploration, aggressiveness, reactivity to humans, and fearfulness were the most common traits studied in pig populations. There was moderate support for relationships between personality traits and physiological responses. Personality was related to other behaviors, such as vocalizations and social aggression. Studies on the genetic control of personality traits are promising, with the heritability of personality traits falling within the range

seen for other traits already selected for in pigs, suggesting that personality can be considered in breeding programs to improve welfare. Pigs with reactive personality types were more influenced by their housing environment than proactive pigs. Housing influenced reactive pigs' immune response, manipulative oral behavior, response in cognitive tasks, play behavior, and gastric lesions, which has serious implications for the management of pigs with different personality types. Few studies explored the predictive power of personality traits on future physiological or behavioral outcomes of pigs, however, there is support for the potential use of personality research in improving pig welfare and productivity. In order to move forward with this field, researchers need to agree on consistent terminology and methodologies, and investigate the reliability, validity, and practicality of common personality measures in pigs.

INTRODUCTION

Definitions and Origins of Personality

There is growing interest in using the concept of personality to study the behavior and fitness of animals, particularly as it relates to their management and welfare. The use of personality in animal management is growing in importance because it incorporates animal-based measures of how individuals are adapting to their environment and can lead to personalized care and management of animals to improve welfare, and ultimately improve physiological measures such as growth, feed intake, immune function, and meat quality (Finkemeier et al., 2018). Personality traits commonly studied in animals include boldness, exploration, sociability, aggressiveness, and activity (Réale et al., 2007; Finkemeier et al., 2018). Words often used synonymously with personality include 'coping style', 'temperament', and 'behavioral syndromes'. The term personality is frequently defined as individual differences that are consistent over time and across contexts (Sih et al., 2004; Dingemanse & Réale, 2005; Zidar et al., 2017). While temperament, behavioral syndromes, and coping style can all be defined in that same way, some researchers provide more specific definitions for each term. For example, temperament is often described as inherited, early appearing individual tendencies or an individual's response to a specific challenge (Jones & Gosling, 2005; MacKay & Haskell, 2015; Rayment et al., 2015). Behavioral syndrome refers to correlated suites of behaviors, such as in the case of more aggressive individuals who also tend to be bolder and their level of aggression in one context (i.e., interspecies interactions) can be similar to their aggression in other contexts (i.e., intraspecies interactions). Ecologists use 'behavioral syndrome' to describe population- or species-level behavioral differences and use 'behavior type' when referring to individual differences in behavior (Sih et al., 2004; see MacKay & Haskell, 2015 for a detailed review of the definitions of temperament, personality, and behavioral syndrome). Coping style is defined as consistent differences in how individuals respond behaviorally and physiologically to stressors (Koolhaas et al., 1999; Zidar et al., 2017). For the purpose of this review, the term 'personality' will be used as a synonym for all terms above to encompass the broad concept of consistent individual differences in behavior.

Consistent individual differences are thought to be a mechanism for organisms to adapt to their environment (Sih et al., 2004; Bolhuis et al., 2005; Koolhaas, 2008). Genetic predisposition, ontogenetic development, early life environment including parental investment, social environment and nutrition have been identified as sources of individual variation that can lead to divergent personalities within a population (Dingemanse & Wolf, 2013). Behavioral variation within a population reduces competition by allowing differential niche specialization, both as it refers to resource use and social interactions (Burgmüller & Taborsky, 2010). Among gregarious species, the mix of personality types within a population can have profound effects on individual and group fitness (Sih & Watters, 2005; Hamilton & Ligocki, 2012; Sih et al., 2014). Not only does individual personality influence social structures, social environment in turn influences an animal's personality, a concept known as 'social niche specialization.' Similar to the ecological concept of niche differentiation, individuals within a social environment adjust their behavior in response to group dynamics (Bergmüller & Taborsky, 2010). Recent evidence shows that animal personality interacts with the social and physical environment to affect fitness (i.e., reproduction, mortality, disease susceptibility, predator avoidance, dispersal success). Thus, personality has powerful effects on ecological outcomes at the population, species, and community levels (Biro & Stamps, 2008; Wolf & Weissing, 2012; Belgrad et al., 2017). Animal personality traits have also been linked to underlying physiological differences among individuals. For example, personality has been associated with variation in immune response, disease and injury susceptibility, growth rate, meat quality, reproduction and maternal traits (Koolhaas & Van Reenen, 2016; Finkemeier et al., 2018). This has major implications for livestock.

There is potential for understanding of pig personality to be used to improve productivity and welfare within the pig industry, particularly when addressing major welfare concerns regarding aggression in group-housed pigs and destructive behaviors such as tail biting, as well as improving overall growth, health, and meat quality parameters. Over the last 27 years, many studies have been conducted to identify personality types in pigs and relate personality traits to behavioral or physiological traits important to the pig industry. However, there is a lack of consistency among the results of these studies, meaning that the implications for improvements to the management and welfare of pigs have yet to be understood or turned into management recommendations that could be applied in practice. This review seeks to identify where evidence is adequate for personality research to guide management and to highlight how personality research effort could be refined to facilitate future development of management recommendations.

Measuring Animal Personality

The most commonly accepted traits used to describe animal personalities are boldness, exploration, sociability, aggressiveness, and activity (Réale et al., 2007; Watters & Powell, 2011; Finkemeier et al., 2018). A generally accepted validation of personality traits is consistency over time and across contexts (McAdams, 1992; Réale et al., 2007; Watters & Powell, 2011). However, consistency does not imply rigidity as individuals may still have a range of reactions to certain situations that may change based on age or context. Therefore, the average of the reactions and differences among individuals should be considered as the consistency in the measure of a trait (McAdams, 1992; Réale et al., 2007; Finkemeier et al., 2018).

Fear and anxiety are assumed to be primitive emotions in animals, related to predator avoidance, and measures of animal personality appear to be strongest when animals are subjected to a stressful situation (Forkman et al., 2007; Réale et al., 2007). With livestock species, researchers are interested in measuring fear and anxiety because the animals within our care are often subjected to novel items or procedures. Livestock species are also often in the presence of and restrained by humans who may be viewed as predators by these animals, despite the fact that they may express reduced fear as a result of domestication (Forkman et al., 2007). Chronic stress caused by ongoing exposure to fearful situations can disrupt growth rate, feeding behavior, reproductive success, and immune function; therefore, it is in the best interest of producers to reduce the amount of fear present within the environment, and to know more about what situations cause fear (Forkman et al., 2007).

Using behavior tests to measure personality traits, such as fear and anxiety, is the most common method of assessing personality in captive animals (Gosling, 2001; Watters & Powell, 2011). Behavior tests such as the novel object test and novel environment tests (i.e., open field test, emergence test, elevated plus maze test; descriptions of commonly used behavior tests are provided in Table 2.2) were originally designed to measure curiosity in rats (novel object test; Berlyn, 1950) and emotionality in rats and mice (Archer, 1973). More recently novel environment and object tests have been used to measure boldness, exploration, and fearfulness in a variety of species (Huang et al., 2018). As with any methodologies used to measure personality traits in animals, careful consideration of the experimental design is needed to ensure the methodology will capture the behavioral nuances of the particular species being studied (Watters & Powell, 2011). Variation across species, sex, and genetic lines are important considerations when assessing responses to behavior tests, as seen in differences in defecation rates in rats and mice in response to a novel environment test (Archer, 1973). For these reasons, it is important to consider the ecology and biology of the species being studied and from this perspective focus on the traits where the natural history would encourage greatest between-individual differences in expression (Gosling & John, 1999; Finkemeier et al., 2018). Five ecologically-relevant categories of personality traits have been suggested for personality traits in animals, along with recommendations for how these traits should be measured: 1) shyness-boldness (measured in a risky but familiar situation), 2) exploration (measured in a novel situation), 3) activity (measured in a familiar situation), 4) aggressiveness (towards conspecifics), and 5) sociability (amount of social interaction shown by an animal; Gosling, 2001; Réale et al., 2007). However, when analyzing personality traits or dimensions in a new context or in a new species, traits from a variety of categories should be measured in order to fully understand the population and to approach the idea of personality dimensions in an exploratory way (Gosling & John, 1999; Watters & Powell, 2011; Huang et al., 2018). Unfortunately, proper validation of methodologies presents numerous challenges for animal personality researchers who are often restricted with respect to time, resources, animal populations, and trained personnel. Validation will be further discussed in the section 'Personality Assessment Methods.'

Literature Review Objective

With this literature review, our objective was to evaluate the studies of personality in pigs with a goal to use this information to guide management practices and to direct future research to address knowledge gaps. To achieve this goal, we summarized the methods used in the literature and highlighted the themes and trends present, while also addressing the issues and inconsistencies currently present in the literature and in applying findings in practice.

LITERATURE REVIEW METHODS

A literature review was conducted from the Web of Science database using the scientific (*Sus scrofa*) and common names for pigs (pig, swine, sow, boar, gilt, and barrow), along with the terms ‘personality’, ‘temperament’, ‘behavioral type’, ‘behavioral syndrome’, and ‘coping style.’ Searches were conducted as “pig personality,” “pig temperament,” “pig behavioral type,” “pig behavioral syndrome,” “pig coping style,” “swine personality,” “swine temperament,” etc. (using all terms listed for the animal name and personality synonym and with both British and North American English spelling conventions). The Web of Science database searches these terms equivalently to “pig AND personality,” etc. The time span for the search included studies published between 1864-2018 and no language exclusions were applied. Empirical studies from peer-reviewed journals were retained for further review if the abstract indicated the study was relevant to our objective. We did not include terms for specific personality traits (e.g., aggressiveness or fearfulness) in the search, as our objective was a focus on studies investigating overall personality constructs or methods of assessing personality. Additional articles were found using references cited in the literature collected during the initial search. Conference proceedings and abstracts are not included in this review because they lack methodological details, which were of interest in this review. Articles were reviewed to collect information on purpose of study, personality term used, animal information (sample size, age, sex, breed), methods used for assessing personality, results of study, as well as any results assessing reliability or validity of the methods used.

RESULTS

Review of the studies of personality in pigs

Literature Search Results

The systematic search yielded 83 articles relevant to the objective of this review, which are listed in Table 2.1 with the source citation, study objective, personality-related term used, sample size, breed and age of the pigs studied, and methods used. The years of publication for these articles ranged from 1991-2018. Figure 2.1 depicts the frequency of pig personality papers published in each year in that range.

'Coping style' and 'temperament' were the most commonly used personality synonyms, with 67.5% of the articles using 'coping style', 20.5% using 'temperament', and only 8.4% using 'personality', 1.2% using 'behavior type', and 2.4% using more than one term.

Animal Information

Sample sizes studied in the articles ranged from 12 to 10,033 pigs, with a median sample size of 94 pigs. A variety of purebred breeds, breed crosses, and species were used in the studies, including Duroc, Landrace, Yorkshire, Hampshire, Chester White, commercial crossbreds, Pitman-Moore minipigs, Vietnamese minipigs, Yucatan minipigs, Göettingen minipigs, wild boar, White-lipped peccary (*Tayassu pecari*), and Collared peccary (*Pecari tajacu*). Pigs studied ranged in age from 0 days to 8 years old. The majority of studies (73.5%) concluded by the time the pigs were 6 months of age, 14.5% of the studies concluded when the pigs were between 7 and 10 months of age, and 12% observed pigs over 1 year of age. Over two-thirds (63.9%) of the studies observed both sexes while 31.3% observed only female pigs, and 4.8% looked solely at males.

Personality Assessment Methods

The 83 studies examined used a variety of personality assessment tests. The most popular test was the backtest, which was used in 67.5% of the studies. In most of the studies (67.5%), more than one test was used to assess personality types. In all but two of the studies, the authors stated which personality traits or dimensions they were attempting to measure with the tests they used. Some authors explicitly stated a particular trait such as “fearfulness” or “aggressiveness” (54.2%). Others stated they were measuring general “coping style” (57.8%), “behavioral differences/strategies” (6%), “temperament” (2.4%), or “personality” (1.2%) instead of naming a specific trait. Table 2.2 provides a list of the behavior tests used to assess personality along with lists of the traits being measured, according to the study authors. Researchers often used different names for what appeared to be similar tests based on the study methods; therefore Table 2.2 also provides a description of each test to enable comparison of results across studies that may have used different terminologies originally.

In addition to the wide range of tests used, the diverse way in which specific tests were applied makes comparisons across studies difficult. For example, with novel object tests, some researchers such as van Erp-van der Kooij et al. (2002) and Reimert et al. (2013) conducted tests in the animals’ home pen while others such as Hayne and Gonyou (2003) and Friel et al. (2016) brought pigs to a novel test area. Even further, if pigs were brought to a test arena, there was no consistency with respect to whether pigs were habituated to the arena or the amount of time they were given to habituate prior to starting the tests. For example, Asher et al. (2016) gave pigs a 5 min habituation period the day prior to the first novel object test, Hayne & Gonyou (2003) gave the pigs 2 min immediately prior to the test, while Ruis et al. (2002) did not provide a habituation period. Some novel object tests were also conducted in succession with other tests. For example, the researchers would bring a pig into a novel arena for an open field test, and then introduce a human for a human approach test, and then the human would leave a novel object as they left (Hayne & Gonyou, 2003) while other researchers conducted these tests separately (for example: Forkman et al., 1995; Brown et al., 2009; Friel et al., 2016). There was also variation in whether novel object tests were conducted on isolated animals as seen in de Sevilla et al., 2009 and Friel et al., 2016 or on an animal as part of a group as seen in Brown et al., 2009 and Reimert et al., 2013. Conducting tests under multiple conditions is a way to test pigs' responses across situations and therefore is useful in understanding personality. However, a problem arises when a test conducted under different conditions is treated as always measuring exactly the same personality trait when it may be equally likely that different traits are being measured. Further validation of behavior tests would help elucidate how different test conditions, including conducting multiple tests in succession or the social context, affect pigs' responses and help us further elucidate which specific traits are being measured. Additionally, tests were conducted at different ages, and sometimes repeated multiple times on the same population with variable intervals between sessions. When tests were repeated, some researchers considered data from the repeated tests as separate measures often without reference to the risk of carry-over effects from one session to the next, while some averaged the data to make a single measure.

The backtest will be discussed as another specific example of the variations that can occur in methodologies used to assess personality within a single and widely used test. The backtest was adapted from the tonic immobility test in chickens and is frequently used as a measure of coping style, where pigs are classified as proactive (high-resisting pigs) or reactive (low-resisting pigs; Hessing et al., 1993; Zebunke et al., 2015). It remains unclear what specific personality trait the backtest is measuring in pigs. Most researchers simply said they were used the backtest to measure 'coping style,' while two researchers specified 'fear' as the trait being measured (Erhard & Mendl, 1999; Erhard et al., 1999). The backtest was the most consistently implemented test across studies due to its simplicity but even so, there were still inconsistencies in how the test was performed. The procedures used by Hessing et al. (1993) were often referenced but few details were provided causing the following researchers to interpret the procedures differently. Pigs were always tested individually outside of their home pen and held on their backs typically for 1 minute (though two studies conducted the backtest for a 5-minute duration; Erhard & Mendl, 1999; Erhard et al., 1999). Few studies specified how the pigs were placed on their backs and when specifics were provided, there was variability such as pigs being placed in a V-cradle (de Sevilla et al., 2009), held on a feedbag on a table (Melotti et al., 2011) or placed on the floor (Forkman et al., 1995). Most studies recorded some combination of the frequency, duration, and/or latency of resistance or struggle attempts (Zebunke et al., 2017). There were also differences in whether the test was conducted repeatedly on the same pig and if so, the number of times each pig was tested varied, as did the length of time between repeated tests. In studies by Bolhuis et al. (2000, 2003, 2004, 2005a, 2005b, 2006), the test was conducted at 10 and 17 days of age. Hessing et al. (1993) conducted the study 5 times over the first 3 wk of age. Zebunke et al. (2015) conducted the backtest at 5, 12, 19, and 26 days of age and Archer et al. (2003) only at 7 wk of age.

Recent studies by Zebunke and colleagues (2015; 2017) aimed to validate the use of the backtest by comparing intra- and inter-test consistency and assessing the influence of classification method on the results. The backtest was conducted 4 times on the same pigs and latency, duration, and frequency of struggling were recorded. Responses were compared across the 4 tests and showed moderate repeatability. There was not clear evidence for two distinct coping strategies but rather that the pigs fell on a continuum between proactive and reactive (Zebunke et al., 2015). The relationship of the backtest variables with variables recorded at mixing, in human approach, novel object, and open door tests were compared. There was low to moderate inter-test consistency suggesting that the backtest was capturing some aspect of personality, but not distinct personality types (Zebunke et al., 2017). A combination of test repetitions and variables were used to compare 4 types of classification methods to classify animals into proactive and reactive based on their distribution. Additionally, the differences in classification between correlation analysis and category analysis were assessed. The classification methods used impacted the results, with some classification methods causing low numbers of animals to be classified as either proactive or reactive. The best method for classifying animals used the latency and duration of struggling across all 4 observations (Zebunke et al., 2017). However, despite these efforts to validate the backtest using inter- and intra-test consistency, researchers still do not have a clear understanding about what trait is being measured by the test. The inconsistent and ambiguous results seen across studies may be due to variation in methodology across studies or because the backtest is an inappropriate method for measuring personality traits in pigs.

Besides the diverse methodologies employed in administering behavior tests to measure personality traits, another issue seen within the pig personality literature was with the statistical methods used to analyze the data. Statistical analyses used for personality assessment varied widely across studies. When comparing behavioral responses across multiple situations in order to identify personality types, correlation (47.8%) and principle components/factor analysis (34.7%) were frequently implemented. The use of principle components or factor analysis in studies on animal personality has been criticized for their incorrect application due to the mistakes outlined by Budaev (2010), such as failing to specify the use of a correlation or covariance matrix, failure to test or report tests and results of sampling adequacy and providing explanations for factor rotation and number of factors retained. Researchers using principal component and factor analyses need to assess the sampling adequacy of their matrices and provide detailed information about how they conducted these analyses to allow them to be critically evaluated and reproduced.

Another issue in the pig personality literature was failure to report reliability for the tests used. Reliability is how consistent a measure is at capturing the desired variable or alternatively can be described as the level of error in the measurement (Martin & Bateson, 2007; Bartlett & Frost, 2008). Failure to report test reliability is not unique to pig personality research but is a consistent problem in personality studies of other species as well (Gosling, 2001). In applied animal behavior studies, interobserver reliability and repeatability are commonly used measures of reliability (Dalmau et al., 2017). Reliability was reported in 24.1% of the pig personality studies examined in the present literature review, with repeatability as the most common measure used. Repeatability refers to the consistency in the measure compared to the same measure taken in identical situations within the same subject (Bartlett & Frost, 2008). Repeatability is a measure of reliability and can be informative about the robustness of a behavior test. Given that across-time consistency is typically regarded as a necessary component of personality, this low use of repeatability analysis is surprising. However, there are issues in the use of repeatability in that animals, especially pigs, readily habituate to repeated tests causing low to moderate repeatability among measures taken across tests (Dalmau et al., 2017). Because an animal's response to tests can change with repeated exposures, using repeatability as a measure of reliability has been questioned, and it has been suggested that the first exposure is the most appropriate measure of a personality trait (Forkman et al., 2007). Repeatability values for the different tests are reported in

Table 2.3. Repeatability values for personality tests had correlation coefficients ranging from 0.11-0.92. The human approach test had the lowest repeatability, suggesting that pigs may habituate quickly to the presence of humans or that their response may depend on the human used in the test. The novel object test, which is widely used across the personality literature, also had relatively low repeatability, which may suggest pigs also habituate quickly to novelty. Alternatively, pigs' response in this test might be dependent on other conditions, such as the object used, whether the pig was tested alone or in a novel arena. The food competition and food motivation tests had the highest repeatability. This suggests that the pigs' response to competing for food with conspecifics is relatively consistent. A meta-analysis on repeatability of behavior (activity, affiliation, aggression, antipredator, courtship, exploration, foraging, habitat selection, mate preference, mating, migration, parental, and other) across species of different taxa revealed the average repeatability is 37% (Bell et al., 2009). This analysis did not include data on domesticated animals, but many of the repeatability values presented in studies of pig personality fall around this average, suggesting these tests are capturing important information on pig personality. It might be expected that behavior in a controlled setting, such as on a farm or in a laboratory, would be more repeatable than behavior measured in the wild, but repeatability in the field has been found to be higher than in a laboratory (Bell et al., 2009). Time interval between studies also affected repeatability estimates, with repeatability decreasing as time between measures increased. Differences in repeatability depending on the age and sex of the animals have also been documented (Bell et al., 2009). These factors should be taken into account when assessing the repeatability of personality traits in pigs and should be used to guide future studies on reliability of personality assessment methods. Reproducibility, the consistency of a measure under changing conditions (Bartlett & Frost, 2008), is a measure of reliability that is often missing from the animal personality literature and appears to be a major issue.

Finally, few studies have attempted to validate the methodologies used in animal personality research. Validity addresses whether the measurements taken allow truly representative answers to the scientific question being asked (Martin & Bateson, 2007). Validity in behavior tests for animals can be measured by comparing results across tests that are meant to measure a single trait, by comparing an animal's behavioral response in a test to their physiological or neurobiological response (Blaszczyk, 2017), and by using psychotropic drugs to compare pigs' response with and without pharmacological intervention (Donald et al., 2011). To validate the use of the open field test in pigs to measure fear, pigs were tested in with multiple interventions including treating pigs with a stress-reducing drug, providing the pig a familiar conspecific during the test, and observing how pigs' response changed with repeat exposures to the test (Donald et al., 2011). Many of the tests and traits used in animal personality studies have been adapted for use across species (Huang et al., 2018). For example, behavior while being run through a weigh scale has been used as a general measure of temperament for pigs (D'Eath et al, 2009), similar to how chute exit speed is used to assess temperament in cattle without further validation of the ecological relevance of this test in pigs. Only five studies in this review explicitly stated an aim to validate personality trait measures, and all of them used the backtest. Responses in the backtest were compared to aggressive behaviors towards conspecifics (Geverink et al., 2002; Zebunke et al., 2017) and physiological measures (Spake et al., 2012; Krause et al., 2017). Comparing behavioral responses across multiple test types is a method of testing validity; however, when multiple tests have been used to assess personality in pigs, it is unclear whether researchers were attempting to measure the same trait across multiple contexts (fearfulness in a novel object test vs. fearfulness in a human approach test; Janczak et al., 2003a), or if they assumed different tests were measuring distinct personality traits (exploration/fearfulness in a novel object test vs. reactivity to humans in a human approach test;

Brajon et al., 2016). Results often showed weak correlations between different behavior tests suggesting each test could be measuring distinct personality traits or that the tests were failing to capture personality traits at all (Huang et al., 2018). It is likely these tests are capturing distinct personality traits, but it is not always clear what specific trait. In order to properly capture personality traits in a species, it is recommended to apply multiple tests and measures in a variety of contexts to identify the prominent personality traits in that species (Huang et al., 2018). Studies on pigs have used this approach but due to the vast differences in methodologies applied and a focus on identifying dichotomous coping styles, pig personality research is still a long way from identifying valid personality traits and tests. Future validation studies should move away from the proactive-reactive coping styles perspective, use a variety of tests in different contexts, and utilize pharmacological interventions to validate tests for personality traits in pigs, similar to Donald et al., (2011). Frameworks for ecologically valid tests and traits have been proposed for use in animal personality research, suggesting five categories: shyness-boldness (or reactivity, emotionality, or fearfulness; Gosling, 2001) measured by animals' responses in a risky, but familiar situation; exploration, where an animal's response to a novel situation or towards a novel object is evaluated; activity levels monitored in a familiar situation; aggressiveness towards conspecifics; and sociability, measured by the level of social interaction an animal displays (Gosling, 2001; Réale et al., 2007). Future studies on pig personality could adopt this framework to provide consistency in this area of research, or alternatively, experts on pig behavior could create a framework specific for pigs. This would allow for comparisons across studies and the ability to synthesize the information for application to the management and welfare of pigs.

Themes and Trends in the Pig Personality Literature

The stated objectives for the reviewed studies have been consolidated into eight categories. Some studies had more than one objective, and therefore were included in the total count for each relevant category. The categories included: comparing behavioral responses across situations to identify personality types of pigs (n=23), investigating relationships between personality and physiological parameters (n=20), examining how personality influences the prevalence of other behaviors (i.e., tail biting, maternal behavior, vocalizations, impulsivity, social aggression; n=17), exploring the heritability or genetic determination of personality (n=16), studying the effects of early-life or current housing environment on personality (n=8), testing the consistency of behavior tests in identifying personality (n=7), considering the role of personality on learning and cognition (n=5), and predicting future behavioral or physiological outcomes of the pigs based on their personality (n=5).

Comparing behavioral responses across situations to identify personality types

Comparison of the behavioral responses of pigs across different situations to identify personality types of pigs was the most commonly studied topic in pig personality research. The multiple contexts studied included using behavior tests designed to provide a stressor or challenge to the pigs or by observing behavior in typical commercial situations, such as in the home pen, at feeding time, or aggression after being placed into a new social group. Table 2.2 provides a list of the behavior tests used to assess behavior types in pigs. Figure 2.2 depicts pairwise comparisons between the behavior tests used by researchers under this objective. Classifications of relationships using slight, low, moderation, and high were determined as outlined in Martin & Bateson (2007). Relationships between test were ‘consistent’ if all the studies comparing the tests reported a relationship. Relationships between tests were ‘mixed’ if some researchers reported a relationship and others did not. The backtest, human approach test, novel object test, and food competition test were the most frequently used. The backtest had consistent but low relationships with the emergence, food competition, and open field/novel object tests and a moderate relationship with the social competition test. The human approach test had consistent but low relationships with the open door and resident-intruder tests, and moderate relationships with the handling-other and emergence tests. The food competition test only had low relationships with aggression at mixing and the food motivation test.

The backtest was used in 60.8% of the studies included in this category. In many of these studies, researchers were interested in investigating the theory that there are two personality types of pigs (i.e., two distinct coping styles), where pigs fall into proactive and reactive types. The response during a backtest was used to categorize the pigs as proactive, reactive, or intermediate (Zebunke et al., 2017). The pigs' responses in other situations were observed and compared to these classifications. Under the proactive versus reactive pig type hypothesis, proactive animals tend to be more aggressive, bold, and rigid in their behavioral responses. In contrast, reactive animals tend to be more shy, passive, and flexible (Koolhaas et al., 1999). The evidence for coping styles in pigs is mixed. Half of the studies investigating whether there were two distinct categories of coping styles found evidence in support of this theory and the other half did not. The inconsistent results seen from studies using the backtest are likely caused by some of the issues previously mentioned in this review, such as unclear hypotheses regarding what trait this test was measuring, inconsistent methodologies when performing the test, and different approaches used for describing the distribution of backtest responses in the population and for statistical analysis. However, the primary issue with reliance on the backtest for measuring personality in pigs is the lack of understanding on what personality trait this test measures and the inconsistent results likely indicate that is it not an ecologically relevant test for pigs.

Nearly half of the studies (47.8%) comparing behavioral responses across situations looked at inter-test correlations between test variables. In general, most significant correlations between test variables were low to moderate. A number of studies (30.4%) went beyond the coping style theory to explore the number of personality dimensions in pigs by measuring the pigs' responses to multiple tests, then using principal components or factor analysis to find the number of components or factors within the study population. As described previously, a framework of 5 key traits, or dimensions, have been attributed to animal personality including fearfulness, activity, aggressiveness, sociability, and exploration (Gosling, 2001; Réale et al., 2007). Most of the studies using principle component or factor analysis found 3 dimensions in the data, but the number of dimensions found ranged from 2 to 5. Exploration and aggressiveness were frequently identified as independent dimensions. Reactivity to humans was also identified as a dimension in multiple studies. This trait is not included in the framework typically used to study animal personality from an evolutionary ecology perspective but that would be important to consider for a personality framework specific to domestic animals because domestication has generally reduced animals' fear towards humans (Forkman et al., 2007) and human-animal interactions are prevalent in animal industries (Hemsworth, 2003). According to this framework, fearfulness is measured by observing an animal's response to a risky but familiar situation (Réale et al., 2007). In many of the tests, such as human approach, novel object, and open field, the researcher specified fearfulness as the trait being measured but these tests were conducted in a novel arena, which would limit the researchers' ability to identify that fearfulness independently of exploration. The match between hypothesized personality dimensions in existing frameworks and the suitability of tests to detect and differentiate between personality dimensions should be considered and addressed in future studies. Sociability was also not a trait typically measured in the pig literature as many of the interactions with conspecifics targeted aggressive responses rather than investigating affiliative social interactions (Camerlink & Turner, 2013). Sociability was identified as a dimension in one study by the use of a social dependence test (Forkman et al., 1995). There are consistent personality dimensions present in pig populations but in order to move forward in identifying pig personality dimensions, a framework specific to pigs needs to be developed with clear criteria for how to measure each one. The framework of 5 dimensions suggested by Gosling (2001) and Réale and colleagues (2007) is a good starting point for future studies on pigs.

Surprisingly, the novel object test had few significant relationships with other tests despite its heavy use in pig personality research. The novel object test had weak relationships with the handling-movement test and food motivation test. The latency to contact a novel object was a reliable method of assessing fearfulness in pigs by Dalmau and colleagues (2017) as indicated by across-time repeatability, but the tests were done in a group in the pigs' home pen. The location of the home pen in the building had an effect on the pigs' response, with pigs housed towards the back of the room having a longer latency to approach the object than pigs housed at the front of the room with more frequent exposure to human presence and novel stimuli (Dalmau et al., 2017). The ambiguous results of the novel object test may be due to the differences in how the test was conducted across studies. Alternatively, these results could indicate that this test is not ecologically valid for pigs in the way researchers expect it to be. Pigs are naturally curious, generalist omnivores, so novelty may not be something inherently fearful to them.

Overall, the comparisons between variables of the different behavior tests are convoluted, and until the validity of tests are better understood, comparisons across tests may be difficult to interpret. Pigs' behavioral responses are consistent across situations which would be indicative of stable personality types in pigs (Hessing et al., 1993, 1994; Erhard et al., 1999; van Erp-van der Kooij et al., 2002; Janczak et al., 2003; Adock et al., 2015; Horback & Parsons, 2016, 2018; Zebunke et al., 2017), with traits related to exploration (Adcock et al., 2015; Horback & Parsons 2016, 2018), aggressiveness (Hessing et al., 1993; Ruis et al., 2000; Horback & Parsons, 2016, 2018), and reactivity to humans (Giroux et al., 2000; Horback & Parsons 2016) being the most readily identified. Comparisons of variables across tests can provide additional insight into the personality traits in pigs, but many of the relationships were low to moderate in strength or inconsistent. However, comparisons across studies should be treated with caution due to vast differences in methodologies used to assess and categorize pigs. Researchers need to be more consistent in their experimental designs and analyses, have a better understanding of how experimental design affects the traits being measured, and ask whether the methods being used are ecologically relevant to pigs to better understand how many personality dimensions are present in pig populations.

Investigating relationships between personality types and physiological parameters

The second most commonly studied topic in the pig personality literature is how personality relates to physiological parameters such as overall health, immune response, growth rate, meat quality and stress response. Figure 2.3 depicts the relationship between behavior tests used to measure personality traits and measures of physiological parameters.

The backtest was used in 17 of the 20 studies in this category, so similarly to many of the studies reviewed above, researchers investigated the differences between pigs classified into proactive and reactive coping styles. Physiological differences in coping styles were found in 76.4% of the studies, with only three studies reporting no difference between coping styles and one reporting ambiguous results. For example, when housed in a metabolism chamber, proactive pigs had lower average daily gain and energy metabolizability than reactive pigs, suggesting they were more stressed by the change in environment, supporting the theory that proactive pigs are more rigid in their response to their environment (Geverink et al., 2004a). Reactive pigs housed in barren environments also had different immune responses compared to reactive pigs in enriched environments and proactive pigs in either environment (Bolhuis et al., 2003). Proactive and reactive pigs also differed in their stress response, with proactive pigs displaying a sympathetic response to stress and reactive pigs expressing a parasympathetic response (Hessing et al., 1994a). Proactive and reactive pigs also had different behavioral responses to an apomorphine challenge (Bolhuis et al., 2000), physiological responses to a restraint test (Geverink et al., 2002b), heart rate and vagal tone during resting, feeding, and handling (Krause et al., 2017), immune responses (Schrama et al., 1997), and production parameters such as leanness and carcass grading (van Erp-van der Kooij et al., 2000) though backfat thickness and loin muscle areas were similar (Cassady, 2007). Pigs of different coping styles differed in their average daily gain before but not after weaning, but there were conflicting results on which coping style gained more weight pre-weaning (Cassady, 2007; Camerink et al., 2014). The combination of individuals of each coping style in a pen affected average daily gain, carcass weight, carcass classification, and meat quality. Pigs in pens of equal numbers of proactive and reactive pigs had better productivity. Pens composed mostly of reactive pigs had more stomach wall damage at the post-mortem exam compared with pigs from mixed pens or pens with more proactive individuals (Hessing et al., 1994b). In studies that did not use the backtest to classify pigs by coping style, relationships were found between coping styles (as determined by responses in an open field/novel object test and restraint test) and the density of opioid receptors in the brain (Loijens et al., 2002) and feed intake at various time points (Salder et al., 2016).

There appears to be moderate support for a relationship between personality traits and physiological parameters that suggest using personality as a management tool could have positive benefits for pig management by managing pigs in a more individualistic manner that improves health outcomes and productivity in targeted ways. There are data to suggest that managing the combination of personality types within a pen could affect productivity and welfare (Hessing et al., 1994b), but the feasibility of identifying personality types in a management setting efficiently is currently a problem because of the time, training, and personnel required to reliably and consistently measure these traits (Watters & Powell, 2011). Additionally, while there do seem to be links between personality traits and physiological parameters that could be considered in the breeding and management of pigs, these relationships are as yet unclear and seem to be highly dependent upon a variety of factors such as housing environment, test procedures, and the age of the pigs when physiological variables are measured. Future research should focus on teasing apart the relationship between these variables and personality traits.

Examining how personality influences the prevalence of other behaviors

Major welfare concerns within the pig industry include behaviors such as tail biting, inappropriate maternal behavior, and stereotypies (D'Eath & Turner, 2009). Exploration of how personality traits relate to these behaviors could have important implications in improving the welfare of pigs by using an animal-based measure of welfare that can help pig managers intervene to prevent problem behaviors (Finkemeier et al., 2018). However, no consistent relationships have been found when personality traits have been compared to maternal behaviors, tail biting, stereotypies, and impulsivity; a trait that could influence the prevalence of the aforementioned behaviors.

When comparing vocalizations to personality type, pigs classified as proactive in the backtest vocalized more while being restrained with a nose sling (Geverink et al., 2002). Additionally, types of vocalizations have been shown to be consistent within individuals across the contexts of a social isolation test and human approach test (Leliveld et al. 2017). If vocalizations are linked to certain personality traits, this could help pig managers identify desirable and undesirable traits to help in making breeding and culling decisions. However, more in-depth research would need to be done to get to this point of practicality in on-farm management.

Social aggression among pigs is a major welfare concern in the pig industry especially following placement of pigs into new social groups, so it is unsurprising that a number of studies have investigated the role of personality type on aggression towards conspecifics. Pigs classified as proactive in the backtest are consistently more aggressive after mixing into a new social group. Specifically, proactive pigs are quicker and more likely to initiate aggressive interactions, spend more time engaged in aggressive interactions and spend more time bullying other pigs that do not retaliate (Bolhuis et al., 2005; Melotti et al., 2011). Pens with more pigs classified as proactive also had higher lesion counts, higher body temperatures, and higher concentrations of urinary catecholamines and plasma ACTH after regrouping (Ruis et al., 2002). However, contrary to these results, no difference was found between proactive and reactive pigs in their aggressive behavior in a resident-intruder test (D'Eath et al., 2002) although the social context of this test differs greatly from that of a group mixing scenario in a neutral pen. Low but significant genetic correlations between aggressive behavior at mixing and response to a handling-movement test were found, suggesting that social aggression is a component of a suite of traits that are part of pig personality (D'Eath et al., 2009). Proactive and reactive pigs also differed in their response to social support and social isolation tests with reactive pigs being more alert when isolated than when with a familiar pen mate (Reimert et al., 2014). Reactive pigs also show a higher physiology stress response and more exploratory behavior when isolated than proactive pigs (Ruis et al., 2001). Aggressiveness is a consistent personality trait in pigs, with pigs showing consistent fighting strategies and behavior in one social challenge that are also predictive of behavior in other social challenges (Erhard et al., 1997; D'Eath et al., 2009; Camerlink et al., 2016). Therefore, understanding aggressiveness as a personality trait can have very real implications pig management. Finding practical solutions to identifying and grouping different personality types would have positive impacts on the management and welfare of group-housed pigs.

Exploring the heritability or genetic determination of personality

The development and maintenance of personality types within a population is the product of an interaction between genes and environment. The genotype, gene expression, including its epigenetic regulation, and parental effects can all predispose an individual to a certain personality type (Biro & Stamps, 2007; Dochtermann et al., 2015). Although the heritability varies between traits, personality has an estimated average heritability of 0.52 across species with aggressiveness and antipredator behavior appearing to have consistently higher heritability than other traits (Dochtermann et al., 2015). The heritability of personality is within the range of traits that are already being selected for in pig breeding, such as weight (0.18-0.32), loin muscle area (0.34), and backfat (0.58; Wurtz et al., 2017). This means that if pig personality is related to improved production and welfare, personality traits can be incorporated into breeding programs if doing so would result in improvements in economic traits that are not currently being realized and costs of measuring behavior can be overcome. A heritability of between 0.10-0.56 has been reported for traits measured in the backtest, human approach test, and handling tests (D'Eath et al., 2009; Köhn et al., 2009; Holl et al., 2010; Rohrer et al., 2013; Scheffler et al., 2014a; Iversen et al., 2017). Low to high genetic correlations have been reported between personality traits measured in different tests and feeding behavior, growth, and aggressiveness (D'Eath et al., 2009; Köhn et al., 2009; Holl et al., 2010; Rohrer et al., 2013; Scheffler et al., 2014a). Candidate genes for coping behavior have been identified using a genome-wide association study (Ponsuksili et al., 2015). The results of the above studies suggest that personality traits are under some degree of genetic control in pigs. However, personality traits are developed through the interaction among genes, environment, and experience. Incorporating personality traits into breeding programs may predispose pigs to exhibit certain personality types, but how genes and the environment may interact to influence the personality types ultimately developed by the pigs is unclear. Further research into this relationship would be worthwhile in addressing concerns in both production and biomedical industries.

Understanding breed and species differences is important when studying and managing pigs in commercial production and other captive settings, such as in zoological facilities or in biomedical laboratories. There are differences in personality between breeds of domestic pigs (de Sevilla et al., 2009; Yoder et al., 2011; Val-Laillet et al., 2013) and personality differences between two species of peccaries have also been found (Nogueira et al., 2015). However, no differences in personality were found between domestic pigs and wild boar crosses (Špinka et al., 2000). There were also no personality differences between naturally bred and cloned pigs (Archer et al., 2003). Pigs selected for positive social breeding values (a beneficial heritable effect on the growth of penmates; Camerlink et al., 2013) were more likely to approach a novel object and human, but there were no other differences in personality based on selection related to social breeding values (Reimert et al., 2013). The results of these studies suggest differences in personality between different groups of pigs may be present which is important to consider in future studies of pig personality or when making management decisions.

Studying the effects of housing environment on personality

Pig housing systems have become a primary welfare concern for consumers, particularly the lack of enrichment, aggression in group-housing systems, and restriction of movement and stimulation in individual gestation stalls. As such, numerous studies have investigated the relationship between housing environment and personality type. The results of these studies suggest that pigs that are reactive in the backtest are more influenced by their housing environment than proactive pigs and that housing environment influenced reactive pigs' immune response, manipulative oral behavior towards penmates and non-food items, ability to complete a cognitive task, play behavior, and incidences of gastric lesions (Bolhuis et al., 2003, 2004, 2005, 2006; Melotti et al., 2011). Pigs classified as proactive in the backtest had won more fights if they were from enriched housing but were overall more aggressive regardless of housing environment (Bolhuis et al., 2005, 2006; Melotti et al., 2011). When relative influence of rearing environment or current environment has been investigated, current housing appears to be more influential. For example, pigs reared in enriched environments and switched to barren environments show less activity, including less play and exploration, even when compared to pigs that remained in barren environments. Pigs switched from enriched to barren environments also showed increased levels of oral manipulative behavior towards pen mates and more gastric lesions at slaughter. These differences in behavior were particularly apparent in pigs that had been classified as reactive in the backtest (Bolhuis et al., 2006). The results of these studies provide support for an effect of housing environment on the behavior of pigs of different personality types. However, it should be noted that studies from other research groups found no difference between pigs of different backtest classifications or found that proactive pigs also show differences based on housing environment (Geverink et al., 2004; Kanaan et al., 2008; Melotti et al., 2011).

Testing the consistency of behavior tests in identifying personality

Studying animal personality specifically to improve the management and welfare of animals is a relatively new area of research. There have been many questions regarding the appropriateness of different behavior tests in identifying personality types in pigs, particularly how consistent they are, as discussed in the section 'Personality Assessment Methods'. Responses in the backtest, human approach test, novel object test, and open door test showed low to moderate consistency over time. The studies reviewed here were conducted on pigs of varying ages with different intervals between tests. Amount of time between repeated tests is an important factor to consider, as it has been shown that shorter intervals between repeated tests leads to more consistency between test results than longer intervals (Scheffler et al., 2014b). Reliability and validity of behavior tests used in studying pig personality are crucial areas of research that are needed in order to move forward in understanding the implications of individual pig personalities on their management and welfare.

Considering the role of personality on learning and cognition

Pig cognition has been tested using cognitive bias tests, mazes and Go-No Go tasks (an operant conditioning task where pigs distinguish between two stimuli, one of which is linked to a reinforcer; Lind & Moustgaard, 2005). Housing environment and human handling can influence learning and cognition in pigs. Proactive pigs are more active and bolder towards novel situations, but are less flexible in coping with changing environments, whereas reactive pigs are more receptive to environmental cues, take longer to explore new environments, and are more flexible (Bolhuis et al., 2004; Jansen et al., 2009). These differences in behavior make reactive pigs generally better at solving cognitive challenges, such as reversal learning in a T-maze task, although housing environment can greatly influence reactive pigs' responses (Bolhuis et al. 2004). Backtest classification was also related to pigs' responses to novel environment and memory tests, with proactive pigs, in general, being more bold, active, and vocal. The interaction between housing and backtest classification was related to pigs' response in the memory test also, with proactive pigs from enriched environments being more active in subsequent memory trials compared with barren housed proactive pigs or reactive pigs. Backtest classification was not related to the number of errors or time to complete the memory test, however (Jansen et al., 2009). Pigs labelled as reactive in a backtest were more hesitant of a novel object if they had been housed in a barren environment, compared with reactive pigs in enriched environments or proactive pigs in either environment, providing evidence that personality type interacts with past experiences to influence cognitive bias (Asher et al., 2016). Personality traits and past experiences also influenced pigs' ability to complete a Go-No Go task, particularly influencing the number of sessions needed to learn the task successfully (Lind & Moustgaard, 2005; Brajon et al., 2016). Thus, there appears to be evidence that personality type interacts with environment and past experiences to influence learning and cognition in pigs, and that some personality types are more likely to be affected by negative experiences than others. These findings could influence study results in a variety of disciplines, and careful consideration should be made regarding housing environment and human-animal interactions to ensure refinement of experimental techniques.

Predicting future behavioral or physiological outcomes based on personality

One goal of researching personality in pigs is to gain the ability to use behavior tests at a young age to identify personality types from which to predict later behavioral and physiological outcomes. This would allow pig caretakers to make informed management and breeding decisions to maximize efficiency of resources and would allow more individualized care that could improve welfare. However, due to the complexity of animal personality, inconsistencies currently present in pig personality research, and the lack of research in this area, applied ethologists are far from this goal. Two studies found that personality traits were related to later growth (discussed below; Giroux et al., 2000; van Erp-van der Kooij et al., 2003) while one found no relationship (Geverink et al., 2002). High social rank and a passive response to stressors were associated with post-weaning growth in early weaned piglets (Giroux et al., 2000), while pigs classified as proactive in a backtest at 10 and 17 days of age had higher daily weight gain in the suckling and fattening periods, respectively (van Erp-van der Kooij et al., 2003). Pigs showing more fear towards human in a human approach test at 8 wk of age had poorer reproductive performance at 1st parity (Janczak et al., 2003b). In a study by Horback and Parsons (2018), activity at 5 wk of age predicted activity at 1st parity and low fear of humans at 3 mon of age. Resistance to being held and cautious behavior at 5 wk of age, and response to humans handling her first litter predicted aggressive/dominant behavior at 1st parity. Response to handling of pre-pubertal gilts observed at 5 weeks of age has been related to behavior at their first parity (Horback & Parsons, 2018). These results could have promising implications for breeding sows if these results are reproducible in future studies. Currently, the predictive power of personality traits is unknown. While a few studies show positive results (Giroux et al., 2000; van Erp-van der Kooij et al., 2003, Horback & Parsons, 2018) these were done on pigs at different stages of production and using different methods, making comparisons across studies difficult.

RECOMMENDATIONS FOR FUTURE STUDIES

The purpose of this paper was to review studies on pig personality in order to highlight the issues currently present in this area of research and identify the knowledge gaps in most need of addressing. The study of personality in pigs is relatively new. However, studies of pig personality have been steadily increasing in recent years, which means that a framework specific to pigs aimed at outlining correct terminology and methodologies is needed. With a consistent framework in place, results would be more easily compared across studies, bringing us closer to being able to make practical recommendations to pig managers for incorporating pig personality information into their breeding, care and welfare.

Based on this literature review, we have identified four major issues with personality studies in pigs. First, studies investigating pig personalities often have unclear hypotheses regarding what personality traits are being measured by behavior tests. Second, there are inconsistent methodologies across studies in test and statistical methodologies that can influence study results and make comparisons across studies difficult. While some variation in test methodology is expected, the way in which pigs are tested could affect which traits are actually being measured. For example, whether pigs are tested alone or in a group or in a familiar or novel environment. Not enough is known about how these test conditions influence pigs' responses, and therefore tests conducted under varying conditions cannot be said to be measuring the exact same trait as similar tests without further validation. This leads to the third issue seen within the literature, which is the lack of testing and reporting on reliability and validity of behavior tests. In the studies that have assessed reliability, behavior tests used in pigs generally have at least low to moderate repeatability, which is promising for future applications. The relevance of the specific tests to assess personality with respect to pigs' behavioral ecology needs to be further investigated to narrow down the most appropriate tests for measuring desired personality traits. Currently tests measuring aggressiveness and food motivation have found consistent results, suggesting these are appropriate tests for pigs. Lastly, the age of the pigs used in studies of pig personality is a major concern. Personality traits can be influenced by age and experience (Janczak et al., 2003; Forkman et al., 2007) and most of the studies included in this review concluded before the pigs were 6 months of age. Therefore, little is known about how personality changes as pigs age and when personality may become more stable, limiting the scope of the applicability of this research on farm.

Based on these issues present in the literature, we have a number of recommendations for future studies. Future studies on pig personality should move away from the backtest and coping styles hypotheses. The backtest was used in 67.5% of the studies included in this review even though it is unclear what personality trait this test is actually being measured. While it does appear that the backtest is capturing some aspects of personality, the results of backtest studies have been inconsistent suggesting that it is likely not an ecologically valid test of personality in pigs. The framework of ecologically valid traits and tests proposed by Gosling (2001) and Réale and colleagues (2007) could be used as a starting point moving forward. Validation of tests used to measure pig personality should also be a top priority in future studies. To validate tests, pigs should be tested in multiple test situations, such as individually or in a group and in familiar and novel environments to elucidate how test situations influence pigs' responses. Following an ecologically valid framework and having a better understanding of validity of tests used on pigs will help make studies more consistent, thus improving our ability to make comparisons across studies and provide recommendations to pig managers. It is also recommended that researchers interested in pig personality conduct longitudinal studies on pigs starting at birth and continuing well through maturity. Longitudinal studies would provide insight on which traits remain consistent as pigs age, allowing us to identify traits that could be used to predict future outcomes and can be used to make management decisions.

In summary, pigs appear to have personality types that are related to or affected by factors important to their management and welfare including physiology, housing environment, social behavior, and cognition. However, the field of pig personality research currently has issues that prevent the application of this information to making realistic management recommendations. Future studies on pig personality need to be reliable and valid, built on assessment of traits and using tests that are ecologically relevant to pigs and that can be consistently applied across studies.

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APPENDIX

Table 2.1. *A list of the 83 peer-reviewed journal articles used in this review.* Study objectives (include: identifying categories of pigs (personality type), physiological parameters (physiology), relationship with other behaviors (behavior), genetic influence (genetics), effects of housing (housing), consistency of behavior tests (consistency), learning and cognition (cognition), and predicting future outcomes of the pigs (predicting)). Personality assessment methods include: activity/behavior in home pen (HOME), aggression at mixing (AGG), backtest (BT), delay discounting task (DDT), emergence test (ET), extinction test (EXT), food competition test (FC), food motivation test (FM), handling-movement (HM), handling-other (HO), human approach test (HAT), novel object test (NOT), novel rope test (NR), open door test (ODT), open field test (OFT), resident-intruder test (RI), restraint test (RT), social challenge test (SC), social dependence test (SD), social isolation test (SI), and towel test (TT).

Source Citation	Study Objective	Term Used	Sample Size	Breed	Age	Personality Assessment Used	Other Methods Used
Adcock et al., 2015	Personality type	Coping style	20	Yucatan mini pigs	28-36 wk	FC, HAT, NOT, SI	Saliva sampling
Archer et al., 2003	Populations	Temperament	17	Duroc	0-27 wk	BT, HO, TT, HOME	Naturally bred vs. cloned pigs, food preference test
Asher et al., 2016	Cognition	Coping style	36	Large White x Landrace	6-10 wk	SI, NOT	Barren vs. enriched housing, cognitive bias test
Bolhuis et al., 2000	Physiology	Coping style	20	Great Yorkshire x Dutch Landrace or Great Yorkshire x Dutch Landrace	1-18 wk	BT	Apomorphine injection
Bolhuis et al., 2003	Housing, Physiology	Coping style	38	Dutch Landrace x Yorkshire	1-9 wk	BT	Immunization
Bolhuis et al., 2004	Cognition, Housing	Coping style	60	Pietrain x (Large White x (Duroc x British Landrace)) and Pietrain x (Great Yorkshire x Dutch Landrace)	1-8 wk	BT	Barren vs. enriched housing, T-maze
Bolhuis et al., 2005a	Housing	Coping style	60	Dutch Landrace x Yorkshire	1-19 wk	BT, HOME	Barren vs. enriched housing

Table 2.1. (cont'd)

Bolhuis et al., 2005b	Sociality	Coping style	60	Yorkshire x (Yorkshire x Dutch Landrace)	1-4 wk	BT, AGG	Barren vs. enriched housing
Bolhuis et al., 2006	Housing	Coping style	120	Yorkshire x Landrace	1-10 wk	BT, HOME,	Barren vs. enriched housing, weight gain, feed intake, pathological exam at slaughter
Brajon et al., 2016	Cognition	Temperament	45	(Yorkshire x Landrace) x Duroc	3-10 wk	HAT, NOT, OFT	Chronic gentle, chronic rough, or minimal contact treatments, Go-No Go task
Brown et al., 2009	Personality type, Consistency	Coping style	120	Purebred Landrace, Yorkshire x Landrace, Yorkshire x Duroc	10-24 wk	HAT, FC, NOT, ODT	Lesion scores
Camerlink et al., 2014	Physiology	Coping style	992	German Landrace and Large White	0-4 wk	BT	Teat order, body weight, general health
Camerlink et al., 2018	Genetics	Coping style	480	Topig-20 and Temp	0-23 wk	BT, HOME	High vs. low indirect genetic effects lines
Cassady, 2007	Personality type, Physiology	Coping style	150	Yorkshire x Landrace sows to Duroc boars	0-22 wk	BT, RI	Average daily gain, backfat thickness, loin muscle area, fat-free leanness
D'Eath et al., 2002	Sociality	Temperament	176	(Large White x Landrace) x Large White	0-7 wk	BT, RI	
D'Eath et al., 2009	Personality type,	Temperament	1663	Swedish Yorkshire and Swedish	10-22 wk	AGG, HM, HOME	Genetic analysis

Table 2.1. (cont'd)

	Sociality, Genetics			Yorkshire x Swedish Landrace			
de Sevilla et al., 2009	Populations	Personality	119	Purebred Large White, Purebred Landrace	4-16 wk	BT, HM, NOT, OFT, RT	
Erhard & Mendl, 1999	Personality type	Coping style	29	(Large white x Landrace) x Large white	3 wk	BT, ET	
Erhard et al., 1999	Personality type, Consistency	Coping style	219	(Large white x Landrace) x Large white	2-10 wk	BT, HM, HO	
Forkman et al., 1995	Personality type	Coping style	110	Yorkshire, Swedish Landrace, Hampshire, Duroc	1-9 wk	BT, EXT, FC, NOT, RI, SD	
Friel et al., 2016	Housing	Coping style	72	Large White x Landrace	6-8 wk	NOT, SI	Barren vs. enriched housing, injuries, vocalizations
Geverink et al., 2002a	Predict	Coping style	52	Pietrain x (Large White x (Duroc x British Landrace))	1-29 wk	BT, FC	Oestrous detection, cortisol, heart rate
Geverink et al., 2002b	Physiology, Behavior	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-14 mo	BT, RT	Cortisol and heart rate response
Geverink et al., 2003	Physiology, Behavior	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-14 mo	BT	Stereotypic behaviors, cortisol, heart rate, pathological examination
Geverink et al., 2004a	Physiology	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-13 mo	BT	Weight gain, climatic respiration chambers

Table 2.1. (cont'd)

Geverink et al., 2004b	Physiology, Housing	Coping style	72	Pietrain x (Large White x (Duroc x British Landrace))	0-14 mo	BT	Individual vs. group housed, immunization
Giroux et al., 2000	Personality type, Predict	Temperament	252	Yorkshire, Yorkshire x Landrace, Duroc	2-4 wk	FC, HAT, OFT	
Goursot et al., 2018	Behavior	Personality	80	German Landrace	5-7 wk	BT, HAT, NOT, ODT	Vocalizations
Hayne & Gonyou, 2003	Personality type	Personality	89	PIC Hybrids	0-18 wk	BT, HM, HAT, HAT/NOT, HOME	Social behavior, teat order, suckling behavior
Hessing et al., 1993	Personality type	Coping style	219	Yorkshire x Danish Landrace	1-15 wk	AGG, BT, SC	
Hessing et al., 1994a	Personality type, Physiology	Coping style	219	Yorkshire x Danish Landrace	1-21 wk	BT, OFT/NOT, SC	ACTH challenge, cortisol and cardiac responses, pathological exam at slaughter
Hessing et al., 1994b	Physiology	Coping style	197	Dutch Landrace x Great Yorkshire	1-25 wk	AGG, BT	Weight gain, post-mortem exam
Holl et al., 2010	Genetics	Temperament	2186	Large White, Duroc, Landrace	22 wk	HM	Weights, backfat thickness, heritability, genetic correlations
Horback & Parsons, 2016	Personality type	Personality	130	PIC 1050	2-4 parity	AGG, FC, HM, HAT, OFT/NOT	Lameness, body condition score, lesions, reproductive success
Horback & Parsons, 2018	Personality type, Predict	Coping style	36	Yorkshire x Landrace	0-18 mo	AGG, ET, HO, HAT	Teat order, response to litter restraint

Table 2.1. (cont'd)

Ison et al., 2015	Behavior	Temperament	24	Large White x Landrace	20-32 wk	HAT, NOT	Farrowing crate vs. pigSAFE pen postural and behavioral changes
Iversen et al., 2017	Genetics	Coping style	992	Tempo x Topigs-20	2-3 wk	BT	Weight gain, fat depth, loin muscle area, heritability, genetic correlations
Janczak et al., 2003a	Personality type	Coping style	92	Danish Landrace x Yorkshire	3-24 wk	BT, HAT, NOT, RI	Estrous checks
Janczak et al., 2003b	Behavior	Personality	89	Danish Landrace x Yorkshire	8 wk to 1st parity	HAT, NOT	Maternal behavior, reproductive success
Jansen et al., 2009	Cognition	Coping style	24	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	1-12 wk	BT	Barren vs. enriched housing, exploration maze, memory test, general activity, posture, and location in maze
Jensen et al., 1995	Personality type	Coping style	42	Yorkshire/Landrace x Hampshire	0-5 wk	OFT/NOT, RI	Post-partum behavior, post-suckling behavior
Kanaan et al., 2008	Housing	Coping style	90	Yorkshire x Landrace	0-2 wk	BT, SC, SI	Socialized vs. unsocialized piglets, weight gain, injuries, suckling behavior
Köhn et al., 2009	Genetics	Temperament	10,033	Goettingen minipigs	8-24 wk	HM, HO	Genetic analysis
Krause et al., 2017	Physiology	Coping style	14	German Landrace	11-13 wk	BT, HAT	Heart rate, blood pressure, body temperature,

Table 2.1. (cont'd)

							autonomic responses to feeding and HAT
Lawrence et al., 1991	Personality type	Temperament	62	Landrace x Large White	7-8 mo	FC, HM, HAT, NOT, ODT, RT	
Leliveld et al., 2017	Behavior	Personality/ Coping style	120	German Landrace	4-5 wk	BT, HAT, NOT, ODT, OFT, SI	Vocalizations, heart rate
Lind & Moustgaard, 2005	Cognition	Temperament	12	Göettingen minipigs	24-36 wk	NOT	Go-No Go Task
Loijens et al., 2002	Physiology	Coping style	18	Large White x British Landrace	7-8 mo	OFT/NOT, RT	Density of opioid receptors at slaughter
Magnani et al., 2012	Personality type	Coping style	132	Landrace x Large White	1-6 wk	BT, ET, NOT	
Melotti et al., 2011	Social, housing	Coping style	128	Tempo x Topigs-30	2 wk	BT, HOME, AGG	Barren vs. enriched housing, lesion scores
Melotti et al., 2013	Physiology, Behavior	Coping style	16	Duroc x Large White x Landrace	1-15 wk	BT, DDT, AGG	Urinary serotonin and dopamine levels
Nogueira et al., 2015	Populations	Temperament	36	White-lipped and Collared Peccaries	3-8 yr	HM	
Oster et al., 2015	Physiology	Coping style	3555 for backtest, 252 for immune challenge, 48 for gene expression	German Landrace	0-8 wk	BT	Immunization

Table 2.1. (cont'd)

Ponsuksili et al., 2015	Genetics	Coping style	294	German Landrace	0-4 wk	BT	Genetic analysis
Reimert et al., 2013	Populations	Personality	543-1009	Topigs-20 and Tempo	1-4 wk	BT, HAT, NOT, OFT	
Reimert et al, 2014a	Sociality	Coping style	72	Tempo x Camborough	1-11 wk	BT, SI/SD	Cortisol, heart rate
Reimert et al., 2014b	Genetics	Coping style	480	Topigs-20, Tempo	2-23 wk	BT, HAT, NR, OFT/NOT	Positive and negative social breeding value lines, barren vs. enriched housing, saliva, cortisol
Reimert et al., 2014c	Physiology	Coping style	480	Topigs-20 and Tempo	4-23 wk	BT	Positive and negative social indirect breeding values, blood parameters
Rohrer et al., 2013	Genetics	Coping style	2007	Landrace x Duroc x Yorkshire	0-22 wk	BT, HM	Feeding behavior, weight, backfat thickness, genetic analysis
Ruis et al., 2000	Personality type, Consistency	Coping style	128	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	0-25 wk	BT, FC, ODT/HAT	Teat order, ACTH challenge
Ruis et al., 2001	Sociality	Coping style	281	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	0-10 wk	BT	Housed in isolation, blood, saliva, and urine samples, body temperature, weight, feed intake, postmortem exam

Table 2.1. (cont'd)

Ruis et al., 2002	Sociality	Coping style	96	Great Yorkshire x (Great Yorkshire x Dutch Landrace)	0-10 wk	BT, AGG, ET/NOT	Lesion scores, blood, saliva, and urine samples, body temperature, heart rate, growth rate, feed intake
Salder et al., 2016	Physiology	Temperament	192	Yorkshire	12-28 wk	HM	Low- and high-residual feed intake lines
Scheffler et al., 2014a	Consistency, Genetics	Coping style	1382 piglets, 272 gilts	German Landrace, Large White	1-22 wk	BT, HAT	Genetic analysis
Scheffler et al., 2014b	Personality type, Consistency	Coping style	1383 piglets, 272 gilts	German Landrace and Large White	2-22 wk	BT, HAT	
Schouten & Wiepkema, 1991	Behavior	Coping style	22	Dutch Landrace x Yorkshire	Primiparous sows	RT	Stereotypic behavior
Schrama et al., 1997	Physiology	Coping style	24	Dutch Landrace, Finnish Landrace, Great Yorkshire	0-10 wk	BT	High and low hemoglobin groups, climate respiration chambers, immunization, growth rate, food consumption, blood samples
Spake et al., 2012	Personality type	Coping style	575	Not specified	1-6 wk	BT, NOT, RI	Heart rate, weight gain
Spinka et al., 2000	Populations	Temperament	14	Yorkshire x Dutch Landrace, 7 sired by Yorkshires and 7 by wild boars	20-24 mo	HAT	Maternal behaviors, behavioral observations, cortisol levels

Table 2.1. (cont'd)

Spoolder et al., 1996	Personality type	Behavioral type	205	PIC Camborough	12-24 wk	FC, FM, HOME, NOT	
Thodberg et al., 1999	Personality type	Temperament	56	Landrace x Yorkshire	16 wk	HOME, FC, HAT, OFT/NOT, RI	
Thodberg et al., 2002	Behavior	Temperament	40	Danish Landrace x Yorkshire	1st and 2nd parity sows	HAT, OFT/NOT	Maternal behavior
Ursinus et al., 2014	Behavior	Coping style	480	Not specified	0-23 wk	BT, NOT, OFT	Tail biting behavior, tail damage, blood serotonin, cortisol
Val-Laillet et al., 2013	Populations	Temperament	63	Pitman-Moore and Vietnamese minipigs	4-7 wk	ET/OFT/HAT	T-maze, Social reunion/separation Y maze
van Erp-van der Kooij et al., 2000	Physiology, Consistency, Populations	Coping style	1389	Dutch Landrace x Great Yorkshire	0 wk to slaughter	BT	Weight gain, leanness, carcass quality, response to piglet removal
van Erp-van der Kooij et al., 2001	Consistency	Coping style	184	Dutch Landrace x Yorkshire	0-2 wk	BT	
van Erp-van der Kooij et al., 2002	Personality type, Consistency	Coping style	315	Dutch Landrace x Yorkshire	0-12 wk	BT, HAT, NOT, ODT	
van Erp-van der Kooij et al., 2003a	Predict	Coping style	812	Dutch Landrace, Great Yorkshire	0-9 wk	BT	Weight gain, leanness
van Erp-van der Kooij et al., 2003b	Physiology	Coping style	882	Dutch Landrace x Great Yorkshire	0-9 wk	BT	Cortisol levels
Vetter et al., 2016	Physiology	Personality	57	Wild boar	6-34 mo	AGG, NOT	Reproductive success

Table 2.1. (cont'd)

Yoder et al., 2011	Populaions	Temperament	4774	Chester White, Duroc, Landrace, Yorkshire	26 wk	HM	Body weight, backfat thickness, loin muscle area
Zebunke et al., 2015	Consistency	Coping style	3555	German Landrace	0-4 wk	BT	
Zebunke et al., 2017	Personality type	Coping style	120	German Landrace	0-8 wk	BT, AGG, HAT, NOT, ODT, OFT/NOT	

Figure 2.1. *Histogram of number of articles published related to pig personality by year.*

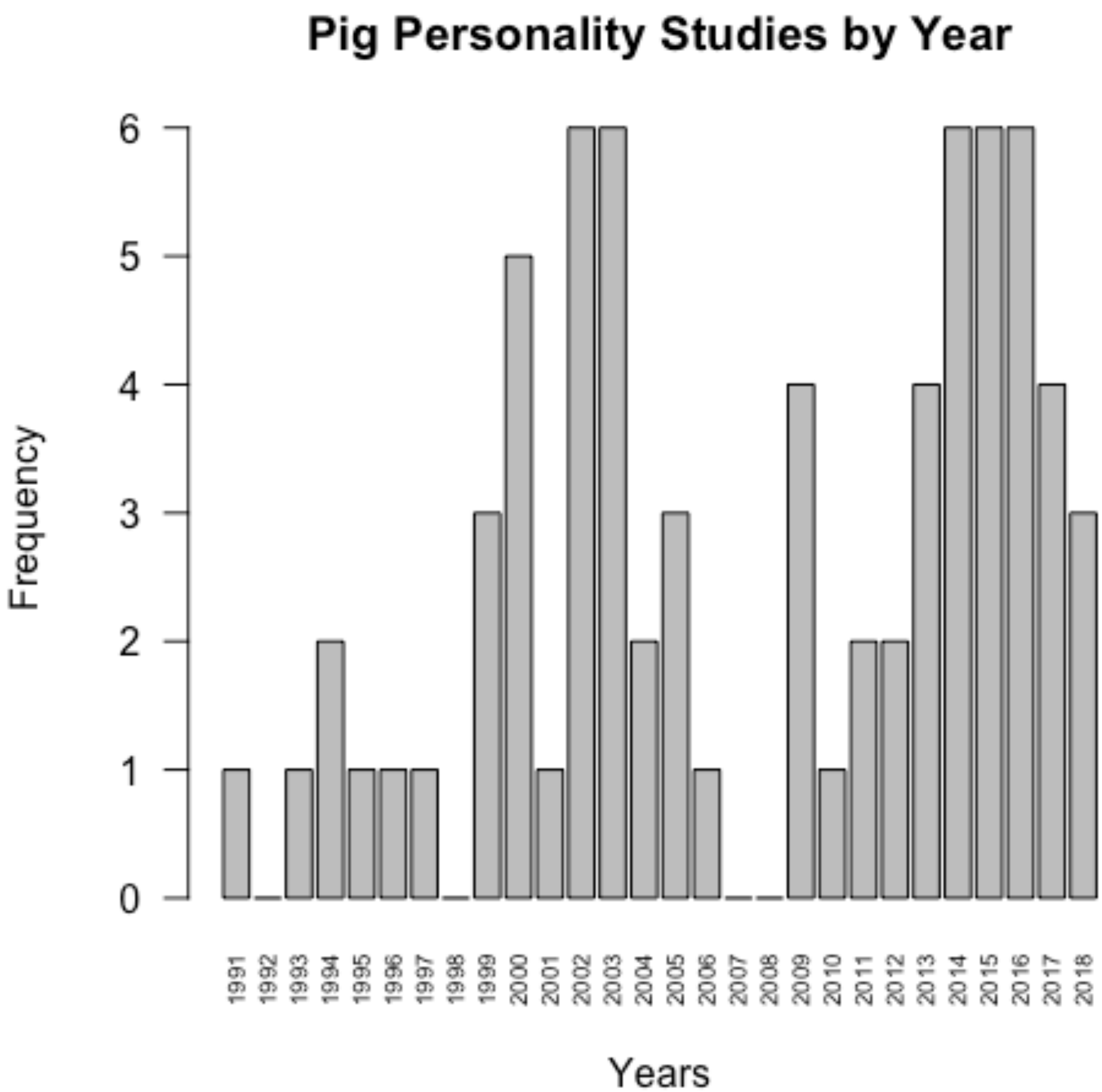


Table 2.2. *Behavior tests used to assess personality in pigs.* Includes the personality traits or dimensions related to in the literature, and a description of how the test is generally conducted.

Test	Personality Trait(s)	Description
Backtest	Coping style, behavioral differences, stress-coping behavior, behavioral strategies, fear, response to restraint, resistance, personality, response to stressor,	Piglet is held on its back and the amount of struggling is recorded.
Delay discounting task	Impulsivity	Pig can press a lever to get an immediate small reward or a lever to get a delayed larger reward.
Emergence test	Timidity, activity and exploration, individual reaction patterns, behavioral reactivity	Piglet is placed in an unfamiliar box with an opening to an unfamiliar arena. Latency to leave the box is recorded.
Extinction test	Persistency	Pigs are trained to expect a food reward in a trough and then the food reward is removed. The duration of trough exploration is recorded.
Food competition test	Social status or hierarchy, aggressiveness	A group of pigs is fed simultaneously or using an ESF feeder. Aggression, success at obtaining food, or order of feeding is recorded.
Food motivation test	Food motivation	Pigs are fasted for a certain amount of time. When the pigs are fed next, their behavior is recorded.
Handling test – movement	Response to handling, ease of movement or handling, reactivity to humans, fear, agitation, coping style, temperament	Pigs are moved down a corridor or through a scale. Ease or speed of pig movement is recorded.
Handling test – other	Challenge, fear, coping style, reactivity to humans	Pig is handled for various tasks and its response is recorded. Tasks can include for injection, being caught and held in a handlers arms, being placed on a table or scale, etc.
Human approach test	Exploration, reactivity to humans, fear and exploration towards humans, boldness, activity, fearfulness, response to handling, emotional reactivity, coping style	Pigs' response to a human is assessed. Human may be familiar or unfamiliar.
Novel object test	Coping style, fear and exploration towards novelty, boldness, activity, emotional reactivity,	An unfamiliar item is presented to the pig and its reaction and interaction with the object is recorded.

Table 2.2. (cont'd)

	individual reaction patterns, response to novelty, fearfulness, anxiety	
Novel rope test	Fearfulness	Ropes are placed in the pigs' home pen. Latency to touch ropes and interaction with ropes is recorded.
Open door test	Motivation and fear leaving pen, boldness, exploration, activity, response to handling, emotional reactivity, coping style	The door of the pigs' pen is opened. The latency to leave the pen and the individual order of pigs leaving is recorded.
Open field test	Exploration, emotional reactivity, fearfulness, anxiety, locomotion activity, response to stress	Pig is brought to an experimental pen and its behavior is observed.
Resident-Intruder test	Aggressiveness	An unfamiliar pig is introduced into the pen of a resident pig. The latency to and amount of aggression between the two pigs is recorded.
Restraint test	Response to handling, response to stressor, coping style	Pig is restrained with a nose sling, with a pig board, or tether and the response is recorded.
Social challenge test	Aggressiveness, coping style	Unfamiliar pigs are introduced in a neutral space and their interactions are recorded. Pigs may be introduced with 1-2 other familiar pigs. For example, three pigs from one litter vs. three pigs from another litter.
Social dependence test	Social dependence	Pig is isolated with familiar pen mates nearby. Its response is recorded.
Social isolation test	Coping style, response to stressor, emotional reactivity	Pig is isolated without contact with other pigs and its response is recorded.
Towel test	Not specified	A towel is placed on the pig's head and latency to remove the towel was recorded.

Table 2.3. *Repeatability for behavior tests used in personality studies, reported as correlation coefficients.* Personality assessment methods include: backtest (BT), emergence test (ET), food competition test (FC), handling-movement (HM), human approach test (HAT), novel object test (NOT), open door test (ODT), open field test (OFT), resident-intruder test (RI), and social isolation test (SI).

Source	**Behavior Test**	**Variable**	**Repeatability**	**Repetitions**	**Age of Animals**
Adock et al., 2015	FC	Social rank	0.77-0.92	2	28-36 wk
Brown et al. 2009	HAT	Latency to first contact	0.21-0.39	3	23 wk
	NOT	Latency to first contact	-0.05-0.32	3	23 wk
	ODT	Latency to exit pen	0.19-0.38	3	23 wk
Cassady, 2007	BT	Time spent struggling	0.38	2	6-17 d
	RI	Latency to attack	0.18	2	33-44 d
D'Eath et al., 2002	BT	Frequency of struggling Duration of squealing	0.33 0.39	2	3-9 d
	RI	Attack latency	0.42-0.48	2	16-19 d
Erhard & Mendl, 1999	BT	Duration of tonic immobility	0.48-0.68	4	3 wk
	ET	Latency to leave	0.52-0.66	4	3 wk
Friel et al., 2016	NOT	Acoustic signaling Duration standing Duration exploring Latency to contact Duration investigating Line cross frequency	0.48 0.36 0.46 0.29 0.02 -0.11	2	6-8 wk
	SI	Acoustic signaling Duration standing Duration exploring	0.58 0.29 0.48	2	6-8 wk
Horback & Parsons, 2016	OFT/NOT	Number of lines crossed Duration exploring Duration lying Latency to contact Duration contact	0.50 0.10 -0.10 0.20 0.20	2	2-4 parity
	HAT	Response to human	0.50	2	2-4 parity
	HM	Ease of handling	0.40	2	2-4 parity
Janczak et al., 2003b	NOT	Duration object investigation Frequency object investigation	0.53 0.44	2	8-24 wk

Table 2.3. (cont'd)

		Latency to object investigation Duration standing Duration room investigation Duration walking	0.28 0.30 0.05 0.10		
	HAT	Duration human investigation Frequency human investigation Latency to human investigation Duration standing Duration room investigation Duration walking	0.33 0.29 0.28 0.28 -0.19 0.02	2	8-24 wk
	RI	Attack latency Duration standing Duration walking	0.34 0.28 0.07	2	8-24 wk
Ruis et al., 2000	BT	Number of escape attempts Duration of escape behavior Number of vocalizations	0.17 0.21 0.23	2	2-31 d
	ODT/HAT	Latency to leave home pen Locomotion in corridor Latency to human contact	-0.06 0.21 0.01	2	10-24 wk
	FC	Aggression	0.61	2	10-24 wk
Scheffler et al., 2014b	BT	Number of escape attempts Duration of escape attempts Latency to escape attempts	0.31 0.33 0.43	2	12 day-22 wk
	HAT	Latency to contact human	0.20-0.52	7	2-22 wk
Spake et al., 2012	BT	Time struggling Struggle attempts	0.34 0.13	2	6-13 d
	NOT	Latency to explore Time exploring Contact latency	0.36 0.20 0.09	2	5-6 wk
	RI	Time from contact to attack Attack latency	0.18 0.11	2	5-6 wk

Table 2.3. (cont'd)

van Erp-van der Kooij et al., 2000	BT	Number of escape attempts	0.39-0.47	3	3-17 d
van Erp-van der Kooij et al., 2001	BT	Number of escape attempts	0.30-0.40	3	3-17 d
Vetter et al., 2016	NOT	Timing of first contact Total duration of investigating	0.17 0.17	9	7 mon
Zebunke et al., 2015	BT	Latency of struggling Duration of struggling Frequency of struggling	0.25 0.39 0.27	4	5-26 d

Figure 2.2. *Flow chart of pairwise comparisons between different behavior tests used to identify categories of pigs.* A total of 23 studies investigated this topic. The tests in the four center circles were the most used, and the numbers represent the number of times those tests were used in those studies. The numbers next to the arrows represent the number of times those tests were compared. The color of the arrow represents the strength of the relationship between those tests. Behavior tests include: activity/behavior in home pen (HOME), aggression at mixing (AGG), backtest (BT), emergence test (ET), extinction test (EXT), food competition test (FC), food motivation test (FM), handling-movement (HM), handling-other (HO), human approach test (HAT), novel object test (NOT), open door test (ODT), open field test (OFT), resident-intruder test (RI), social challenge test (SC), social dependence test (SD), and social isolation test (SI).

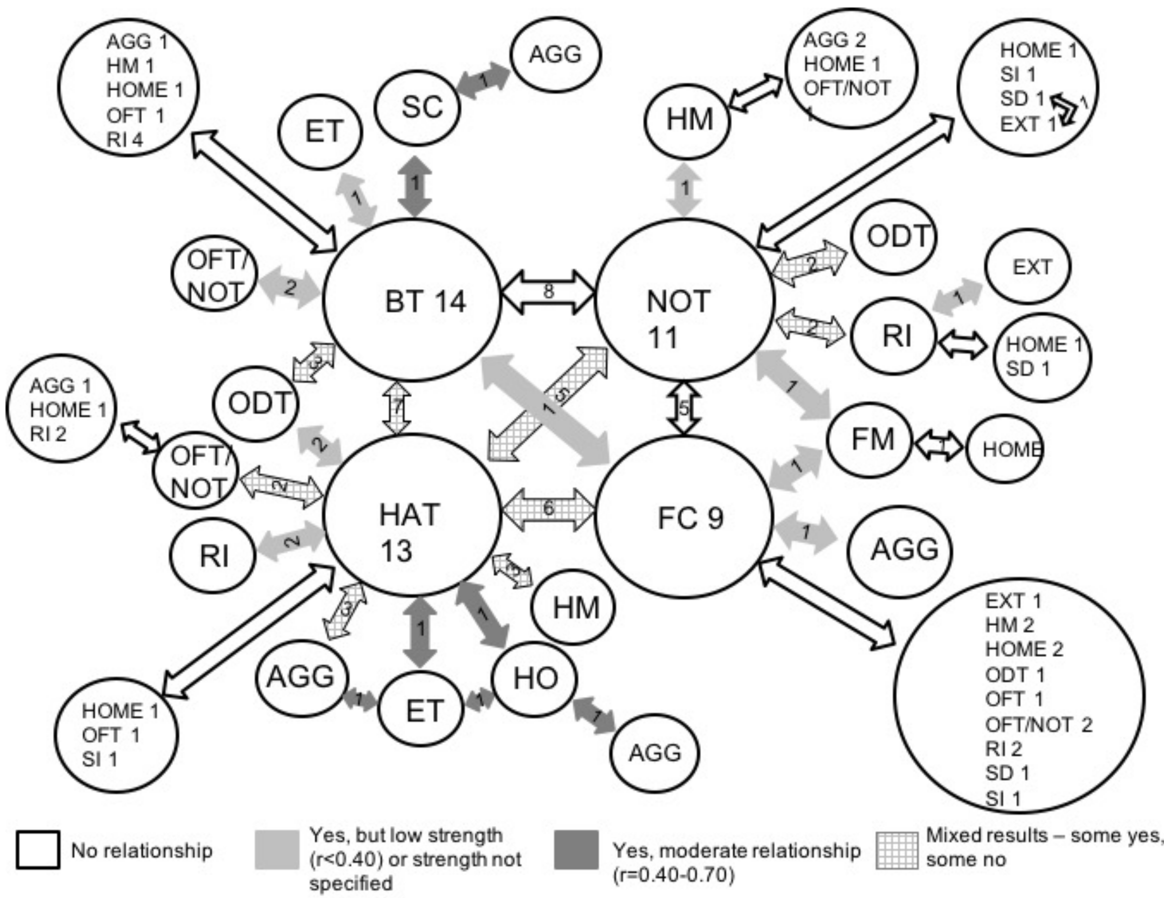
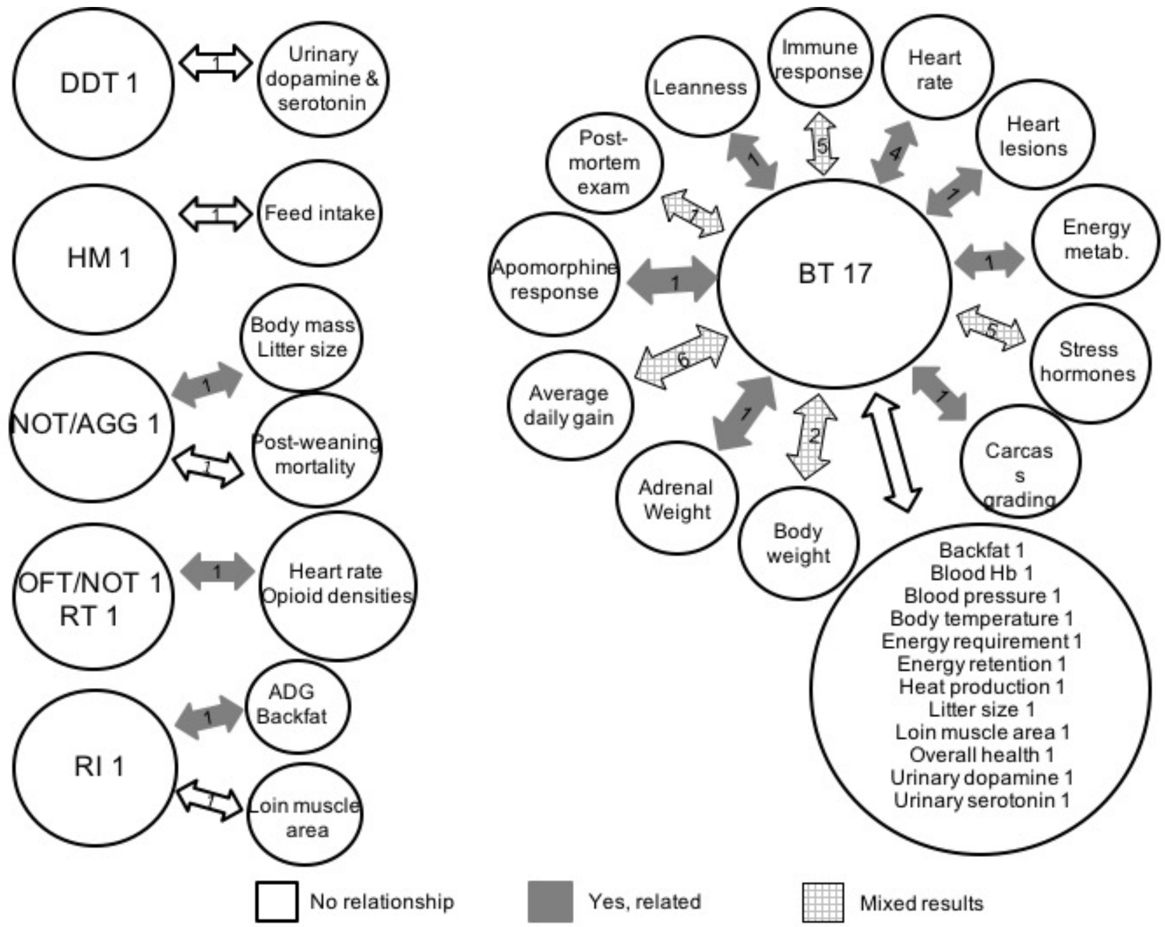


Figure 2.3. *Flow chart of pairwise comparisons between behavior tests and physiological parameters.* A total of 20 studies compared personality traits and physiological traits. The numbers next to the arrows represent the number of times those tests were compared. The color of the arrow represents the strength of the relationship between those tests. Behavior tests include: aggression at mixing (AGG), backtest (BT), delay discount task (DDT), handling-movement (HM), novel object test (NOT), open field test (OFT), resident-intruder test (RI), and restraint test (RT).



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CHAPTER 3: TIME BUDGETS OF GROUP-HOUSED PIGS AND RELATION TO SOCIAL AGGRESSION AND PRODUCTION

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ABSTRACT

Group-housing offers benefits to pigs in commercial production, allowing them to interact with conspecifics and gives them more freedom of movement. However, introduction of unfamiliar pigs can cause increased aggression for 24-48 h as pigs establish social relationships. Producers often house pigs by sex and weight to allow for efficient use of resources. To address this issue, a better understanding of pig behavior is needed. The objectives of this study were to quantify time budgets of pigs following introduction into a new social group and how these changed over time, and to investigate how social aggression influences overall time budgets and production parameters. A total of 65 Yorkshire barrows across 5 pens were observed for aggression and time budgets of behavior at 4 periods: immediately after introduction, 3, 6, and 9 wk later. Pigs were observed for duration of total aggression and initiated aggression (s) for 9 h after introduction and for 4 h in the afternoon 3, 6, and 9 wk later. Time budgets were created by scan-sampling inactive, movement, ingestion, social, and exploration behaviors every 2 min for 4 h in the afternoon and summarizing proportion of time each behavior was performed by period. Least square means of each behavior were compared across time points. Pigs spent most of their time inactive. In general, pig behavior continued to change until wk 6 ($P<0.049$) and then remained the same between wk 6 and wk 9 periods ($P>0.256$). Pigs' non-aggressive behavior and production parameters were compared to aggression using generalized linear mixed models. The time pigs spent on non-aggressive behaviors were related to aggression, particularly time spent inactive ($P<0.034$; except initiated aggression at wk 9, $P=0.793$) and exploring (P<0.036; except for initiated aggression in wk 6 and 9, $P>0.060$). Aggression after introduction and at wk

3 were negatively related to growth rate ($P<0.021$) and loin muscle area ($P<0.039$). These results show how finishing pigs spend their time in commercial facilities and indicate that behavior continues to change for up to 6 wk after introduction to a new social group. The amount of aggression occurring up to 3 wk after introduction could have negative effects on production parameters. These results suggest that efforts to reduce aggression should be implemented beyond the immediate 48 h after introduction, and possibly up to 3 wk after.

INTRODUCTION

Consumers are increasingly concerned with the sustainability of agricultural practices, including the welfare of livestock, leading to a demand for welfare-friendly products (Broom, 2010; Velarde et al., 2015). Naturalness is considered a key component of good welfare, with intensive production systems often viewed negatively in this regard by consumers (Velarde et al., 2015; Thorslund et al., 2017; Hemsworth, 2018). Within the U.S., a major change is occurring in the pig industry as producers transition gestating sows to group housing systems in response to concerns from consumers about sows' inability to perform natural behaviors in gestation stalls (Tonsor et al., 2009a; Hemsworth, 2018). In response to public concerns over animal welfare, ten states have passed legislation banning the use of gestation crates, and over 60 major food companies have pledged to purchase only crate-free pork products, with these mandates requiring producers to transition away from gestation crates by 2022 (Andrews, 2014). However, as of 2018, only 24% of U.S. producers have phased out gestation crates, and those that have done so have invested large sums of money and faced challenges in training personnel to manage group-housed pigs safely and effectively (Pairis-Garcia, 2018). Thus, while group-housing addresses some welfare concerns raised by consumers related to allowing more natural social behaviors, this comes with its own set of challenges.

Group-housing already presents major welfare concerns for pigs at other production stages, such as grow-finisher (Marchant-Forde & Marchant-Forde, 2005). Pigs at this stage are often housed with pigs of the same sex and similar weight to create uniform groups for efficient resource use (Turner et al., 2010). Unfamiliar pigs fight intensely for 24-28 h as they work to establish a social hierarchy following introduction into a new social group, after which lower levels of aggression are typically seen (Meese & Ewbank, 1973). Chronic high levels of aggression can occur in some social groups and contribute to disruptions to growth rate and immune function (Marchant-Forde & Marchant-Forde, 2005). Recent survey data from North American pig producers found that about half of the respondents attempted to minimize aggression when introducing pigs using a variety of techniques such as mixing pigs into a new pen or using a specified mixing pen, mixing pigs at night, using odor-masking agents, providing enrichment at mixing, or socializing piglets before weaning (Ison et al., 2018). Many of these interventions, such as mixing at night, have been shown to merely delay aggression rather than reduce it (Marchant-Forde & Marchant-Forde, 2005). Producers who did not actively attempt to minimize aggression may not perceive aggression at mixing as a top priority despite it being a major welfare concern in the industry (Camerlink & Turner, 2017), meaning that social aggression is still a prevalent welfare issue that needs realistic and implementable solutions.

To address this issue, a better understanding of what constitutes successful group housing is needed so that researchers and producers can work to promote successful social groups. The objectives of this study were to quantify the behavioral profiles of group-housed grow-finish pigs to better understand how pigs in typical U.S. commercial facilities spend their time following introduction into a new social group and pen, and to examine how social aggression influences overall time budgets and production parameters including growth rate, backfat thickness, and loin muscle area. It was hypothesized that the time budgets of pigs immediately after being introduced would be different than the time budgets of pigs 3, 6, and 9 weeks after introduction, with pigs spending more time on aggression and explorative behaviors immediately after introduction than pigs in more stable social groups. It was also hypothesized that pens of pigs that displayed more aggression would have different behavioral time budgets at all time points as a result of unstable social relationships, and that pens with more aggression will negatively impact production parameters as a result of chronic stress.

MATERIALS AND METHODS

All animal protocols were approved by the Institutional Animal Care and Use Committee (Animal Use Form number 01/14-003-00).

Study Population and Housing

The animals used in this study were housed at the Michigan State University Swine Teaching and Research Center (East Lansing, MI, USA). Pigs were moved into grow-finisher rooms at 10 weeks of age (approximately 23 kg) and housed in 4.83 m x 2.44 m slatted-concrete floor pens. Pigs could consume feed *ad libitum* with commercial feed formulated for the age and weight of the animals (NRC, 2012) and had *ad libitum* access to water using nipple with cup water systems. The grow-finish rooms had incandescent light bulbs and received 8 h of full light and 16 h of half-light per day.

A total of 65 purebred Yorkshire castrated males (barrows) were observed across 5 pens. The barrows were housed with 10-15 pigs per pen with pigs of similar weights to minimize variation. Pigs from 3-5 nursery pens were moved into grow-finish pens together. Barrows were housed with 2-5 familiar pen mates from the nursery pens. The rest of the barrows were unfamiliar to them. At 6 weeks after mixing, stable groups of barrows were moved into a different pen in the same room as a way to assess social stability as part of a different experiment. The new pens had the same configuration and resources as the barrows' original pens.

Video Recording and Observations

Pigs were video recorded by Clinton Electronics VF540 Bullet Cameras installed on the ceiling above each pen. These cameras were connected to a digital video recorder (Geovision 1480A) that was set-up to record video events for 24 h immediately after mixing, and again for 24 h 3, 6, and 9 wk later.

Pigs were given a unique mark on their backs using non-toxic markers for the purpose of identifying individual animals. Trained observers recorded aggressive behaviors including reciprocal fighting, attacks, pressing, and head knocks using all-occurrence sampling for 9 h after introduction to a new social group, including 5 h immediately after introduction and 4 h the following morning, and 4 h in the afternoon at wk 3, 6, and 9 after introduction. Time budget behavior was observed by trained individuals using the ethogram in Table 3.1. Pigs were observed using focal-animal scan-sampling every 2 min for 4 h in the afternoon at each of the 4 time periods (immediately after mixing, 3, 6, and 9 wk later).

Production Traits

Pigs were weighed prior to introduction into grow-finish pens and again prior to slaughter. Growth rate was calculated using these two weights divided by the number of days between weights. Backfat thickness (cm) and loin muscle area (cm^2) were measured using B-mode ultrasound (Aloka SSd-500V, Hitachi Aloka Medical America, Inc., Wallingford, CT).

Statistical Analyses

Data analyses were completed using R (Version 1.0.136, R Core Team 2016; Vienna, Austria). Packages used included: xlsx (Dragulescu & Arendt, 2018), psych (Revelle, 2017), lmerTest (Kuznetsova et al., 2017), and car (Fox & Weisberg, 2011).

Aggressive behaviors were summarized into total duration of aggression (s) and total duration of initiated aggression (s). Total duration of aggression was the sum of all bouts of aggression individual pigs were involved in, regardless of who initiated the interaction or the direction of the interaction. Initiated aggression included any behavior where there was a clear initiator of the aggressive interaction, as well as any one-sided aggressive interactions and totaled only for the individual pig that was the initiator.

Time budgets were calculated by taking the proportion of time pigs spent performing each behavior at each time point. Time budgets were compared between time points using least square means with time point as a fixed effect and pen as a random effect. The response variable was proportion of behavior, which was arcsine square root transformed for normality. Normality was assessed by visual inspection of Q.Q. plots. Tukey's HSD test was used to obtain adjusted *P*-values.

To assess the relationship between time budgets and aggression, generalized linear mixed models were fitted for each time point and for each measure of aggression, including total aggression (s) and total initiated aggression (s). The response variable was aggression ($\log_{10}$+1 transformed for normality, which was determined by visual inspection of Q.Q. plots). Fixed effects included proportion of time spent on inactivity, movement, ingestion, social behavior, and exploration, and pen was a random effect.

To assess the relationship between aggression and production traits, generalized linear mixed models were fitted for each production trait for each measure of aggression (total and initiated) and period. The response variables were the production traits, which were inspected for normality by visual inspection of Q.Q. plots. Fixed effects included the measures of aggression (scaled), and random effect was pen.

RESULTS

Pig time budgets and how time budgets changed over time (i.e., immediately after introduction, 3 wk, 6 wk, and 9 wk later) are depicted in Figure 3.1. In general, pigs' behavior continued to change until wk 6, and then remained stable between wk 6 and wk 9.

Pig time budgets were compared to total aggression (Table 3.2) and total initiated aggression (Table 3.3) at all time points. The time pigs spent on non-aggressive behaviors were negatively related to duration of aggression with a few exceptions. Time spent inactive and exploring were negatively related to total duration of initiated aggression at multiple time points.

Total duration of aggression and total initiated aggression at all time points were compared to production variables of growth rate, backfat thickness, and loin muscle area taken prior to slaughter (Table 3.4). Growth rate and loin muscle area were negatively related to aggression after introduction up to wk 3. Neither measure of aggression was related to backfat thickness.

DISCUSSION

Group-housing systems can improve pig welfare through interactions with conspecifics and the ability to display more natural behaviors, but these systems also present a major welfare concern due to aggression seen between pigs as they establish social relationships. As producers work to address this issue, understanding how pig behavior changes over time following introduction to new social groups is important for designing interventions that reduce conflict and improve productivity. For this study, the objectives were to assess and compare the time budgets of group-housed pigs that were recently introduced to a new social group, and 3, 6, and 9 wk later, and to investigate the relationship between non-aggressive behaviors and aggression, and between aggression and production parameters.

It has been reported that pigs in commercial settings spend about 80% of their time inactive, 10% on ingestion, and 10% on other behaviors (Pond & Mersmann, 2001). In the 3, 6, and 9 weeks after introduction to new social groups, the behavioral patterns seen in our population was similar, suggesting that the behavior of pigs in this study is representative of pigs in typical U.S. commercial facilities. We found that pigs spent most of their time inactive, with ingestion as the next most performed behavior in the 3, 6, and 9 weeks after they were placed into finishing groups. It was hypothesized that the time budgets of pigs immediately after being introduced would be different than the time budgets of pigs 3, 6, and 9 weeks after introduction and that pigs would spend more time on aggression and exploration immediately after introduction than in later time periods, and this was indeed the case. Pigs' behavior immediately after introduction was different than their behavior at 3, 6, and 9 wk later with the exception of social behavior after introduction, which occupied a similar proportion of time compared to 3 and 9 wk later. Pigs are most aggressive in the first 48 h after introduction to unfamiliar pigs, but once pigs have established social relationships, aggression sharply declines (Meese & Ewbank, 1973). Not surprisingly, pigs in our study were also most aggressive immediately after introduction to a new social group, with relatively low amounts of aggression seen in the following weeks. For the non-aggressive behaviors assessed, the proportion of time spent on each continued to change until wk 6 then remained stable through wk 9. These data suggest that it can take up to 6 wk for pigs to fully settle into their new social group. This is consistent with previous reports that skin lesions (resulting from aggressive interactions) remain at an elevated level for several weeks after introduction, and that chronic aggression may persist for several months following introduction (Turner et al., 2013).

To date, little research has looked into the relationship between pig time budgets and aggression. It was also hypothesized that pens of pigs that displayed more aggression would have different non-aggressive behavioral time budgets at all time points. Total duration of aggression was negatively related to pigs' time budget through wk 9 with the exception of movement and ingestion at wk 3, suggesting that pigs that engage in more aggression do spend less time on other behaviors. Pigs that were more likely to initiate aggressive interactions spent less time inactive and exploring through wk 3 and less time inactive and engaging in social behavior at wk 6. Our results suggest that interventions that promote behaviors other than aggression, particularly exploration, could be successful in decreasing time spent on aggression. Provision of environmental enrichment, even simply scattering feed multiple times a day (Vermeer et al., 2017), can decrease aggressive interactions in group-housed pigs and promote exploratory behavior and growth (Schaefer et al., 1990; Beattie et al., 2000). Enrichment has not been shown to reduce aggression immediately after introduction, but on-going aggressive interactions in the weeks following introduction are reduced in pigs provided enrichment compared to control groups in barren pens (Martin et al., 2015).

Pigs kept in groups have different feeding patterns compared to those housed individually, with fewer feeding bouts and consumption of more food at each bout (de Haer and Merks, 1992; Bornett et al., 2000). Stress caused by introduction to a new social group can lead to decreased food intake and disrupt growth (Ponds & Mersmann, 2001), which led to our hypothesis that increased aggression would negatively impact production parameters. Immediately after introduction into a new social group, ingestion was lower than at 3, 6, and 9 wk later. Increased aggression immediately after introduction and 3 wk later was negatively related to growth rate and loin muscle area. The negative effect of aggression on growth rate has been documented previously and is a concern in the pig industry as producers may introduce pigs into new social groups several times before slaughter (Camerlink & Turner, 2017; Peden et al., 2018). No relationship to backfat thickness was found in the current study though previous studies have reported that group-housed pigs have slower growth and less backfat than pigs housed individually (de Haer & de Vries, 1993). A negative genetic relationship between skin lesions (used as a measure of social aggression) and loin muscle area has been reported in our population of pigs (Wurtz et al., 2017). Thus, issues associated with aggression in group-housed pigs could be addressed through breeding programs as well as through behavioral management (Peden et al., 2018), although Desire et al. (2015) did not find a relationship similar to those reported by Wurtz et al., (2017). Neither study reported a genetic relationship between skin lesions and growth rate or backfat thickness (Desire et al., 2015; Wurtz et al., 2017).

Investigation of welfare concerns caused by aggression in group-housed pigs have largely focused on reducing aggression immediately after introduction. As the aggression seen within 48 h of introduction is intense and causes an increased risk of injury and can cause other negative effects on pig health and welfare, reducing aggression is a top priority. However, the results of the present study suggest that the negative effects of aggression on production can last for up to 6 weeks following pigs' introduction to a new social group, and therefore interventions focusing on reducing chronic as well as immediate aggression in group-housed pigs would be beneficial.

CONCLUSION

In conclusion, the proportion of time pigs spent on different behaviors changed in the weeks following introduction into a new social group, suggesting that pigs can take up to 6 weeks to acclimate and settle into their environment. Aggression was negatively related to non-aggressive behaviors in pigs' time budgets, suggesting that interventions promoting other behaviors, particularly inactivity and exploration, could help reduce aggression. Although aggression after introduction largely decreases 48 h after introduction to a new social group, aggression occurring up to 3 weeks after introduction had negative impacts on growth rate and loin muscle area. Therefore, future research on aggression in group-housed pigs should focus on finding ways to reduce aggression for weeks not just the days immediately after introduction.

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APPENDIX

Table 3.1. *Ethogram of the behaviors recorded.* (Adapted from Bolhuis et al., 2005) Behaviors were recorded every 2 min for 4 consecutive hours in the afternoon.

Behavior	**Description**
Inactive	Lying on floor, sitting or kneeling or standing without performing any other described behavior
Movement	Walking, trotting, running or changing postures w/o performing any other described behavior
Ingestion	Eating or drinking, interacting with feeder or waterer
Social	Touching or sniffing pen mate; mounting pen mate; pushing penmate out of feeder space; performing any manipulative behavior such as belly nosing, nibbling, or suckling pen mate
Aggression	Fighting, biting, head knocks, pressing, retreating from attack, withdrawal
Exploration	Nosing, chewing, or otherwise manipulating floor or pen fixtures

Figure 3.1. *The least square means of the proportion of time pigs spent on each behavior.* The behavior for finishing pigs compared over four time points (immediately after introduction into a new social group (Introduction), and 3, 6, and 9 weeks after introduction. Error bars represent the 95% confidence interval of the least square mean. Bars with different letters are different from each other ($P < 0.05$, Tukey HSD adjusted).

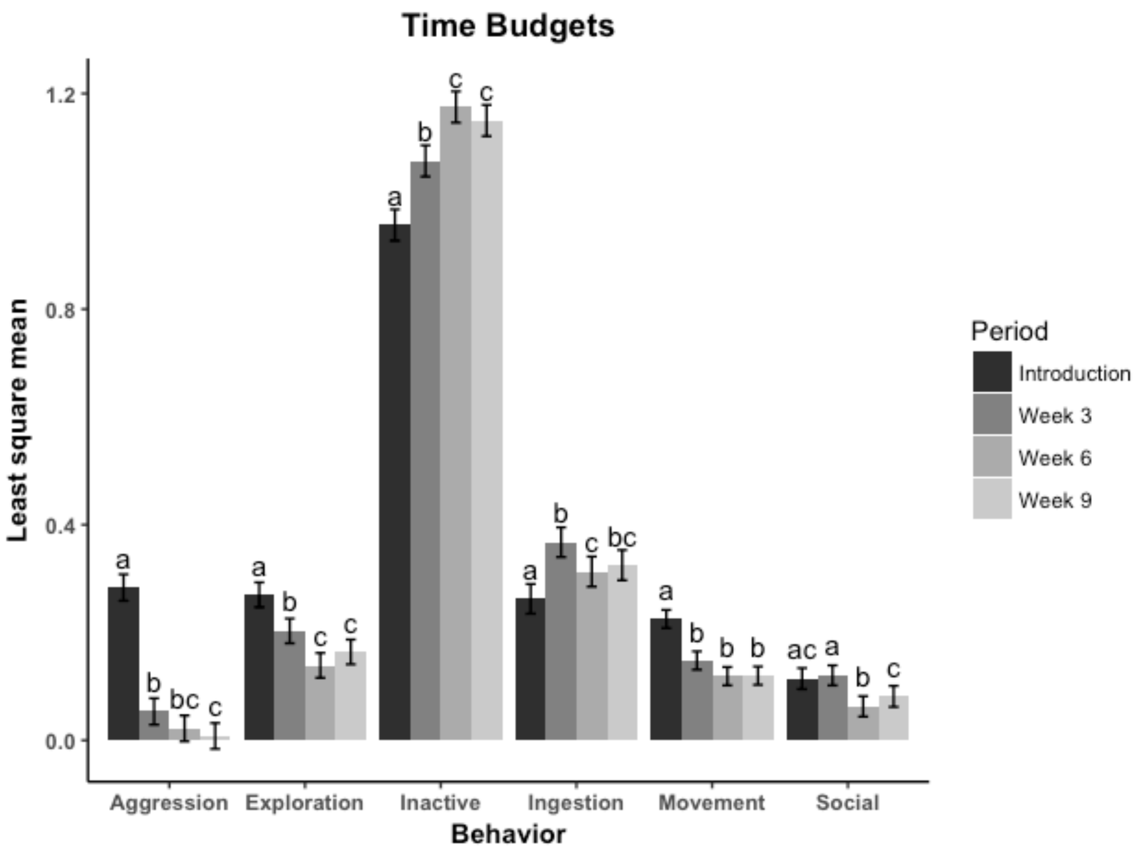

Table 3.2. *Time budgets, presented as proportion of time for each behavior at each time point, were compared to total duration of aggression*. Aggression variables were $\log_{10}$+1 transformed for normality. Pigs were observed immediately after introduction to a new social group and 3, 6, and 9 wk later. * indicates *P*<0.05.

			Slope	**SE**	$\mathbf{F_{(1, 6)}}$	***P***
Total aggression (s)	**After introduction**	Inactive	-3.543	0.478	50.816	<0.001*
		Movement	-3.845	1.422	6.158	0.017*
		Ingestion	-3.594	0.921	14.574	<0.001*
		Social	-1.806	1.410	1.603	0.211
		Exploration	-5.730	1.024	29.015	<0.001*
	3 wk	Inactive	-11.125	4.409	5.981	0.017*
		Movement	-7.120	4.728	2.119	0.151
		Ingestion	-8.974	5.305	3.546	0.065
		Social	-11.103	5.305	4.100	0.047*
		Exploration	-9.406	4.295	4.612	0.036*
	6 wk	Inactive	-37.270	12.900	7.807	0.007*
		Movement	-34.800	13.470	6.167	0.016*
		Ingestion	-33.960	13.130	6.243	0.015*
		Social	-37.260	13.060	7.519	0.008*
		Exploration	-33.800	13.090	6.317	0.015*
	9 wk	Inactive	-42.350	17.190	5.653	0.021*
		Movement	-39.860	18.010	4.585	0.036*
		Ingestion	-40.230	17.310	5.026	0.029*
		Social	-38.200	17.480	4.462	0.039*
		Exploration	-38.330	16.830	4.822	0.032*

Table 3.3. *Time budgets, presented as proportion of time for each behavior at each time point, were compared to total duration of initiated aggression.* Aggression variables were log_{10}+1 transformed for normality. Pigs were observed immediately after introduction to a new social group and 3, 6, and 9 wk later. * indicates *P*<0.05.

			Slope	**SE**	$\mathbf{F_{(1, 6)}}$	***P***
Total initiated aggression (s)	**After introduction**	Inactive	-1.879	0.551	10.442	0.002*
		Movement	-1.276	1.559	0.528	0.473
		Ingestion	-0.930	1.080	0.699	0.406
		Social	-1.153	1.669	0.458	0.501
		Exploration	-5.648	1.183	20.399	<0.001*
	3 wk	Inactive	-13.278	5.471	5.712	0.020*
		Movement	-8.325	5.872	1.947	0.168
		Ingestion	-11.374	5.726	3.818	0.056
		Social	-12.346	6.556	3.464	0.068
		Exploration	-12.876	5.294	5.805	0.019*
	6 wk	Inactive	-32.010	14.22	4.709	0.034*
		Movement	-30.650	14.840	3.911	0.053
		Ingestion	-28.390	14.470	3.566	0.064
		Social	-33.650	14.400	5.010	0.029*
		Exploration	-28.520	14.440	3.677	0.060
	9 wk	Inactive	-5.128	18.857	0.069	0.793
		Movement	-2.937	19.753	0.021	0.885
		Ingestion	-2.333	18.993	0.014	0.906
		Social	-2.905	19.175	0.022	0.883
		Exploration	-4.097	18.467	0.046	0.830

Table 3.4. *Total aggression and total initiated aggression compared to production traits.* Total aggression and total initiated aggression recorded using all-occurrence sampling for 4 continuous h in the afternoon at 4 time points (immediately after introduction, and 3, 6, and 9 wk later) were compared to production traits taken prior to slaughter. Production traits included growth rate, backfat thickness, and loin muscle area. * indicates $P<0.05$.

Period	Production Variable	Aggression, s	Slope	SE	$F_{(1, 2)}$	*P*
Introduction	Growth rate, kg/day	Total	-0.022	0.008	8.011	0.006*
		Initiated	-0.013	0.008	2.402	0.126
	Backfat thickness, cm	Total	-0.00002	0.049	0	0.999
		Initiated	-0.009	0.049	0.031	0.862
	Loin muscle area, cm^2	Total	-0.885	0.454	3.688	0.059
		Initiated	-0.969	0.453	4.415	0.039*
3 wk	Growth rate, kg/day	Total	-0.019	0.008	5.762	0.019*
		Initiated	-0.017	0.008	3.897	0.053
	Backfat thickness, cm	Total	-0.051	0.048	1.074	0.304
		Initiated	-0.009	0.049	0.035	0.851
	Loin muscle area, cm^2	Total	-1.038	0.451	5.048	0.028*
		Initiated	-1.247	0.449	7.269	0.009*
6 wk	Growth rate, kg/day	Total	-0.008	0.008	0.876	0.353
		Initiated	0.003	0.008	0.161	0.689
	Backfat thickness, cm	Total	-0.002	0.045	0.002	0.969
		Initiated	0.023	0.048	0.236	0.629
	Loin muscle area, cm^2	Total	-0.395	0.467	0.688	0.410
		Initiated	-0.237	0.461	0.258	0.613
9 wk	Growth rate, kg/day	Total	-0.011	0.008	1.641	0.205
		Initiated	-0.004	0.008	0.227	0.635
	Backfat thickness, cm	Total	0.006	0.049	0.012	0.914
		Initiated	0.066	0.049	1.807	0.184
	Loin muscle area, cm^2	Total	-0.936	0.462	3.852	0.054
		Initiated	-0.816	0.462	2.960	0.090

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CHAPTER 4: RELATIONSHIPS AMONG AGGRESSIVENESS, FEARFULNESS AND RESPONSE TO HUMANS IN FINISHER PIGS

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ABSTRACT

Mixing unfamiliar pigs is common in modern production, resulting in intense aggression potentially leading to injury and stress. One solution is breeding against aggressiveness. However, in order to anticipate the consequences of such selection, we need to understand how individual aggressiveness is related to other behavior traits. Tests were used to assess three traits of importance to pig producers: interaction with humans, response to handling, and fearfulness. Test responses (human approach (HAT), handling, and novel object (NOT)) were compared with skin lesions for 257 grow-finish pigs, mixed at 10 wk of age. Skin lesions, a reliable proxy for aggressiveness, were counted pre-mixing, 24 h post-mixing, and 3 wk post-mixing. Lesions were recorded by body location (front, middle, rear). HAT was conducted at 14 wk of age in home pens by all-occurrence scans every 30 s for 9 min. Frequency and intensity (low/moderate or extreme force) of oronasal contact with observer was recorded. Activity and reactivity while entering, in, and leaving a weigh crate were recorded in the handling test (14 wk of age). NOT was conducted at 17 wk of age. Pigs were moved to an arena, given a 1 min acclimation period, then 5 min exposure to a novel object (basketball). Pigs were scored for latency to approach within 1 m, 0.5 m, and to touch the ball, and on number of times crossing the 1 m and 0.5 m lines and touching the ball. Generalized linear mixed models compared behavior test variables and lesions. Test responses were compared using a Mantel test. Pigs with more 24 h post-mix front lesions took longer to cross the 1 m line (P=0.049). Pigs with more 24 h post-mix rear lesions interacted intensely with observer (P=0.026). Pigs with more 3 wk post-mix front lesions were

less active in the weigh crate (*P*=0.021) and took longer to touch the ball (*P*=0.033). Pigs with more 3 wk post-mix middle lesions were faster to the 0.5 m line (*P*=0.005), took longer to touch (*P*=0.006), but touched it more (*P*=0.049). There were no significant relationships between behavior tests, suggesting no consistency in responses across contexts. In conclusion, responses in HAT and NOT were related to 24h post-mix lesions, while responses in NOT and handling test were related to 3 wk post-mix lesions suggesting that selecting for less aggressive pigs could have unintended consequences for other important behavior traits and that these relationships should be explored further.

INTRODUCTION

Mixing of unfamiliar pigs is a common practice in modern pig production and results in intense aggression as pigs work to establish dominance relationships. This creates a welfare concern in group-housing systems, as aggression can lead to injury, infection, and stress. The majority of aggressive interactions subside within 48 h; then the groups are considered relatively stable (Meese & Ewbank 1973). However, even in groups with stable membership, dominance relationships can be challenged or reinforced, resulting in prolonged aggression that can disrupt productivity and welfare for the entire pen (Turner et al. 2009; Parent et al. 2012). As a result, there is a need to study social aggression in domestic pigs to help producers better manage group-housed animals to improve welfare and prevent economic loss.

Previous research suggests individual aggressiveness is highly consistent in pigs, with behavior in resident-intruder tests or at mixing predicting behavior in subsequent social challenges. Further, individual variation in fighting strategies is indicative of different aggressive behavior types (Erhard et al. 1997; D'Eath et al. 2009; Camerlink et al. 2016). This variation occurs even between pigs of comparable weight, which largely determines their physical fighting ability (Camerlink et al. 2015). Counts of skin lesions (fresh red marks on the skin) have been used as a proxy for behavioral observations of aggressiveness both immediately after mixing and 3 wk later (Turner et al. 2009; Desire et al. 2015). Skin lesion counts can only provide an estimate of pig aggressiveness but are a tool that can be used by industry to make management and breeding decisions in lieu of in-depth behavioral observations. Lesions have been shown to have high genetic correlations with aggressive behavior, moderate heritability, and repeatability when individual pigs are mixed into different groups, showing that while lesions may be influenced by pen environment, they also can measure an aspect of pigs' individual aggressiveness (Erhard et al. 1997; Turner et al. 2009; Wurtz et al. 2017). The number of skin lesions provides an estimate of the amount of time a pig is engaged in aggressive interactions, while the location of lesions on the body may be a result of a pig's fighting strategy. Front lesions are genetically correlated with pigs engaging in reciprocal fights and delivering non-reciprocated aggression, while rear lesions are genetically correlated with receiving non-reciprocated aggression. Skin lesions obtained immediately after mixing have been shown to be related to skin lesions 3 wk later, suggesting that skin lesion counts obtained in a stable group of pigs may be an indicator of overall aggressiveness and social group instability (Turner et al. 2009).

One proposed solution to mitigate the issue of social aggression in group-housing is breeding for less aggressive pigs. Aggressiveness is thought to be part of a suite of behavioral traits an individual exhibits in both social and nonsocial challenges and is part of their overall personality type (Erhard & Mendl 1997; Koolhaas 2008; Turner et al. 2010). Past research in pigs and other species has shown positive relationships between aggressiveness, boldness, exploration, and activity (Réale et al. 2007; Koolhaas 2008); however, the relationship between aggressiveness and fearfulness in pigs is not yet fully understood (D'Eath et al. 2009; Turner et al. 2010), leaving a knowledge gap that is critical to address to breed against aggressiveness and create pigs better suited for group-housing. Excessive fear and anxiety can disrupt growth rate, feeding behavior, reproductive success, and immune function (Forkman et al. 2007), and livestock, including pigs, are often subjected to procedures involving human contact or novelty (Janczak et al. 2003; Forkman et al. 2007). Therefore, while selecting against aggressiveness, it would be detrimental to inadvertently breed pigs that are more reactive towards humans or novelty.

In this study, we used human approach, handling, and novel object tests to measure pigs' response towards humans, during handling, fear of novelty in relation to each other and aggressiveness. Due to the positive relationship between aggressiveness, boldness, and exploration, we expected aggressive pigs, i.e. pigs with front lesions at 24 h and 3 wk post-mixing, to interact more with the human observer and be intense in their interactions, be easier to handle through a weigh crate, and have a shorter latency to touch a novel object. We expected pigs with more 24 h post-mix rear lesions, more 3 wk post-mix rear lesions, or those with few to no lesions at both time points to be less interactive with human observers, harder to handle through a weigh crate, and have a longer latency to touch the novel object.

MATERIALS AND METHODS

All procedures were approved by the Institutional Animal Care and Use Committee of Michigan State University.

Animals and Housing

The study population consisted of 257 purebred Yorkshire barrows (castrated males) housed at the Michigan State University Swine Teaching and Research Center (East Lansing, MI, USA). The pigs were group-housed in identical grow-finish rooms in 4.83 m x 2.44 m slatted-concrete floor pens with 10-15 pigs each. Four replicates (5 pens/replicate) were conducted. Pigs had *ad libitum* access to commercial feed balanced to meet or exceed the nutritional requirements for animals of this age and weight (NRC 2012). Water was provided by nipple with cup water systems, with one nipple per pen. On average, pigs received 8 h of full incandescent light per day, in addition to about 16 h of half-light from auxiliary incandescent bulbs. Pigs were mixed into grow-finish pens at 10 weeks of age (around 23 kg in weight). Pigs were mixed into new same-sex social groups by weight (mean = 27.4 kg; min = 17.2 kg, max = 37.6 kg) to minimize variation within the pens (smallest range within a pen was 4.1 kg, largest was 8.6 kg). Each new finisher group contained 2-5 familiar pigs from each of 3-5 nursery pens, to make up the 10-15 pigs in each pen. Pigs were strategically mixed to reduce or eliminate remixing of littermates. Thus, in each finisher pen, 2-5 pigs were familiar with each other but were not familiar or related to the remaining 10-13 pigs.

The timeline of lesion scoring and behavior tests used in this study are provided in Table 4.1.

Lesion Scoring

Lesion scoring (i.e., counting of fresh skin lesions) was used to monitor aggressive interactions between individual pigs during mixing and stable events. It was performed by 3 trained personnel to record scores at three time points: a baseline score obtained immediately prior to mixing, a 24 h post-mix score, and a 3 wk post-mix score. Lesions were recorded for three body regions including front, middle, and rear; as per Turner et al. (2006). The front region included the head, ears, neck, shoulders and front legs. The middle region included the back and flank. The rear region included the hind legs, rump, and tail.

Behavior Tests

To determine whether behavior towards a stockperson during a routine pen visit was related to individual aggressiveness, a voluntary human approach test (HAT) was conducted at 14 wk of age in the pigs' home pens, with all pen-mates present. Pens were sampled in a random order, and the same person observed all pigs in a single pen. Back numbers were applied randomly using a non-toxic permanent marker to aid in pig identification. A two-visit methodology was used so that half of the pigs in the pen were observed during each visit to ensure observations for individual pigs were precise. Pigs were categorized based on whether their back number was odd or even. The order of observation for odds and evens was chosen at random. The first category was sampled for all pens, and then observers revisited the pens approximately 40 min following the initial sampling in the same order to collect data from pigs in the second category. To test that this methodology did not contribute to habituation to the observer for the second group of pigs sampled (i.e., an order effect), the first five pens of this study were sampled on two consecutive days. The order in which pigs were observed was randomized each day using their back numbers. Subsequent study replicates were only sampled on one day using the method described.

Observations were made using instantaneous scan-sampling (Altmann 1974) every 30 s for 9 min total. Record was made of whether focal pigs were in physical contact with the observer, as well as type of interaction (biting, nosing, or levering) and intensity of the interaction (neutral or intense). The ethogram used for this test is presented in Table 4.2. The observer stood passively during all interactions. In each test, the observer changed position between three different locations in the pen (front, middle, and back) every minute, for a total of 6 observations per test in each location.

The handling test was conducted at 14 and 17 wk of age. Pens of pigs were moved together down a hallway, then moved one at a time through a chute and into a walk-on weigh crate. The same handler and same observer tested all pigs. The handler was trained to use low-stress handling techniques when moving the pigs at all times to maintain a calm atmosphere and avoid unduly influencing the pig's reaction to being handled. The handler held a sorting board between themselves and the pigs at all times and was instructed to slowly and quietly walk behind the pigs with pig board unless the pig was resistant to moving. If the pig was resistant to moving, the handler would encourage the pig to move forward using a predetermined set of steps, starting with a wave of the hand within the line of vision, then light touches on the back, and finally firm pushes on the back. The observer recorded each pig's behavior and reaction while moving into the crate, while in the crate, and upon leaving the crate using a modified version of the scoring system developed by D'Eath and colleagues (2009; Table 4.3). Low scores indicate a reactive, or less cooperative pig, while high scores indicate a more cooperative pig. The observer also recorded weight of the pig while in the crate at both time points.

The NOT was conducted at 17 wk of age. The same observer and handler were present for all tests. The testing arena was 4.3 m x 3.4 m and was a novel environment for the pigs in a separate room down the hall from rooms housing the pigs (thus not entirely out of sound or smell of other pigs). The walls of the arena were lined with black corrugated plastic to eliminate visual distractions while the pig was in the arena, and lines were painted on the floor 1 m and 0.5 m away from the novel object. The sampling order of pens and of pigs within each pen was random. Pigs were individually removed from their home pen and walked down the hallway into the loading area. Each pig was moved through a chute, and then into a walk-in scale used for the previously described handling test. The pig was then moved into the empty novel object arena. Low-stress handling techniques were used throughout to reduce additional stress or arousal prior to testing. Once in the arena, the pig was given a 1 min acclimation period, followed by a 5 min exposure to the novel object (basketball). The ball was placed in a net-bag and tethered to the wall of the arena using a plastic chain to secure it in the designated location. The ball was lowered into the arena by the handler onto a predetermined spot in the far end of the arena from where the animal enters. The test officially began when it touched the floor. The variables recorded during the test were: latency to cross the 1 m line, latency to cross the 0.5 m line, latency to touch the novel object, frequency of 1 m line crossings, frequency of 0.5 m line crossings, frequency of novel object touches, frequency of vocalizations made during the test, frequency of urination and defecation, and frequency of scampers, runs, and escape attempts. After testing, the pig was directed back to its home pen, and the next pig in the pen was brought out for testing. The pen was scraped for manure between tests. This continued until all pigs in a pen were tested. One to two pens were tested each day, and tests were conducted over three to five consecutive days.

Statistical Analysis

All data analyses were completed using R (R Core Team 2016; Vienna, Austria). Packages used include: psych (Revelle, 2016), lme4 (Bates et al., 2015), MVN (Korkmaz et al., 2014), car (Fox & Weisberg, 2011), compositions (van den Boogart et al., 2014), vegan (Oksanen et al., 2017), and gwaR (Steibel et al., 2015).

Human Approach Test

HAT variables were calculated as proportion of observations with the human observer. Due to infrequency of nosing (22%) and levering events (5%), interactions were grouped into neutral interactions (NI; all low/moderate force interactions nosing, biting and levering), intense interactions (II; all extreme force interactions nosing, biting and levering), and all interactions (AI; combined interactions) for further analysis. These three variables were analyzed separately due to collinearity.

To test whether habituation occurred with the two-visit methodology for the HAT, Gaussian linear mixed models were used to analyze fixed effects of day, order, and the interaction of day and order, with pen as a random effect. Intraclass correlation coefficient (ICC) was calculated as well.

Gaussian linear mixed models were used to relate skin lesions and HAT variables. In the model examining 3 wk post-mix lesions, the response variable was number of skin lesions ($\log_{10}$+1 transformed to obtain an approximate normal distribution as determined by visual inspection of the Q.Q. plots). The fixed effects were NI, II, or AI, study replicate, and lesion observer. Weight at mixing was included as a fixed covariate. Pen was included as a random effect. The same model was used for 24 h post-mix lesion scores, with pre-mix lesion score added as a fixed effect to account for lesions present prior to mixing that were not a result of aggression at mixing. The models were fitted separately to lesion scores from each body location at the two time points (24 h and 3 wk post-mix).

Handling Test

Gaussian linear mixed models were used to relate skin lesions and handling test variables. For 3 wk post-mix lesions, the response variable was number of skin lesions ($\log_{10}$+1 transformed). The fixed effects were scores whilst moving into, being in, and leaving the weigh crate, study replicate, and lesion observer. Weight at mixing was included as a covariate and pen as a random effect. The same model was used for 24 h post-mix lesion scores, with pre-mix lesion scores added as a fixed effect. The models were fitted separately to lesion scores from each body location at the two time points (24 h and 3 wk post-mix).

Novel Object Test

Gaussian linear mixed models were used to relate skin lesions with NOT variables. For 3 wk post-mix lesions, the response variable was number of skin lesions ($\log_{10}$+1 transformed). The fixed effects were latency to the 1 m line, latency to the 0.5 m line, latency to touch the ball, frequency of crossing the 1 m line, frequency of crossing the 0.5 m line, frequency of touching the ball, study replicate, and lesion observer. Weight at mixing was included as a covariate and pen as a random effect. The same model was used for 24 h post-mix lesion scores, with pre-mix lesion scores added as a fixed effect. The models were fitted separately to lesion scores from each body location at the two time points (24 h and 3 wk post-mix).

Comparisons between the Tests

In order to compare individuals based on variables measured in different tests, a Mantel test was used. An isometric log ratio was applied to HAT variables to enable analysis as a distance matrix using Euclidean distance. The NOT variables were split into matrices for latency to approach (included latency to approach the 1 m line, 0.5 m line, and latency to touch the ball) and number of times a pig approached and touched the ball (which included the number of times crossing 1 m line, crossing the 0.5 m line, and touching the ball). Separate Euclidean distance matrices were computed for each of them. A Gower's distance matrix was computed based on the frequency of handling scores. The Mantel test between all pairs of distance matrices was computed for the correlation coefficient and its significance was assessed through 10,000 permutations (Legendre & Legendre 1998).

RESULTS

Human Approach Test

When analyzing whether there was an order effect of the two-stage sampling methodology used for HAT, we found that fixed effect of day was significant, with more interactions with the human observed on the second day for both AI ($F_{1,4}$=4.679, *P*=0.028) and II ($F_{1,4}$=7.481, *P*=0.008), but not for NI ($F_{1,4}$=1.723, *P*=0.193). Order of sampling within a day was not significant for NI ($F_{1,4}$=1.461, *P*=0.231), II ($F_{1,4}$=1.839, *P*=0.179), nor AI ($F_{1,4}$=1.625, *P*=0.206). Interaction between day and order within a day was also not significant for NI ($F_{1,4}$=1.561, *P*=0.215), II ($F_{1,4}$=0.417, *P*=0.519), nor AI ($F_{1,4}$=1.478, *P*=0.227). NI had an ICC=0.341 (*P*=0.004), II had an ICC=0.245 (*P*=0.033), and AI had an ICC=0.384 (*P*=0.001). The results suggest that pigs were habituating to the test situation when sampled again on a second day, but that order of testing within a day did not influence their behavioral response to the human.

Distributions of responses during the HAT are listed in Table 4.5. There was a wide range in frequency of interaction with the human observer with some pigs never interacting and some pigs interacting 94% of the time. The mean number of intense interactions was low (7%) but some pigs interacted intensely with the human observer over half the time (56%).

Pigs who were intense in their interactions with a human observer had more skin lesions on the rear of their body 24 h post-mix (Slope=0.374 lesions/intense interaction, SE=0.167, $F_{1,13}$=04.996, *P*=0.026). There were no significant relationships between 3 wk post-mix lesion scores and the three HAT measures (*P*>0.165). Study replicate (24 h post-mix *P*>0.202; 3 wk post-mix *P*>0.051) and weight at mixing (24 h post-mix *P*>0.211; 3 wk post-mix *P*>0.425) did not have an effect on any HAT variables compared with lesion scores, but there was an effect of pre-mix lesion score (24 h post-mix $F_{1,13}$>16.275, *P*<0.01) and lesion observer on all comparisons (24 h and 3 wk post-mix $F_{6,13}$>3.897, *P*<0.01*)*, with the exception of 3 wk post-mix rear lesions (*P*=0.231).

Handling Test

Distributions of handling scores at 14 wk of age and 17 wk of age are presented in Figure 4.1. When being moved into the weigh crate, 9% of the pigs became more cooperative (indicated by a higher score at the 17 wk of age handling test compared to the 14 wk of age handling test), 26% became less cooperative (indicated by a lower score at the 17 wk of age handling test compared to the 14 wk of age handling test), and 65% had the same score at the 14 wk of age handling and the 17 wk of age handling. Whilst in the weigh crate, 34% became more cooperative, 19% became less cooperative, and 47% had the same score. When leaving the weigh crate, 16% became easier to handle, 12% became more difficult to handle, and 72% had the same score. The only significant relationships with lesion scores were found among the 14 wk of age handling responses, therefore 17 wk of age scores (24 h post-mix *P*>0.106; 3 wk post-mix *P*>0.408) are not reported further here, but the implications of these results are presented in the discussion. Overall, the pigs were easy to handle, with scores of 1 (indicating an uncooperative animal) never observed while moving into or leaving the crate. Results of comparisons among 3 wk post-mix skin lesions and handling scores are presented in Table 4.6. Pigs that were more cooperative (less active) in the weigh crate (scores of 2 and 3) had more 3 wk post-mix front lesions ($F_{2,12}$=2.936; score 2: Slope=0.347 lesions/increase in score, SE=0.169, *P*=0.041; score 3: Slope=0.407 lesions/increase in score, SE=0.174, *P*=0.021). There were no other significant relationships with handling scores and skin lesions. Study replicate (24 h post-mix *P*>0.229; 3 wk post-mix *P*>0.111) and weight at mixing (24 h post-mix *P*>0.176; 3

wk post-mix *P*>0.428) did not have an effect on any handling test variables compared with lesion scores, but there was an effect of pre-mix lesion score (24 h post-mix $F_{1,18}$>16.43, *P*<0.01) and lesion observer (24 h post-mix $F_{6,18}$>3.641, *P*<0.01; 3 wk post-mix $F_{2,12}$>3,463, *P*<0.041) for all handling variables compared with lesion scores, with the exception of 3 wk post-mix rear lesions (*P*=0.277).

Novel Object Test

Distribution of pigs' responses for the latency and frequency to cross lines and touch the ball (novel object; NO) are given in Table 4.5. The variables run, scamper, and escape were not presented or analyzed due to low numbers of occurrences. The frequency of vocalizations, urinations, and defecations were not related to skin lesions (*P*>0.377). Minimum scores of 0 s for the latency measures indicate a pig who was already within the 1 m and 0.5 m lines as we lowered the ball, while a maximum of 301 s indicate a pig who never crossed the lines or touched the ball. There was a full range of responses for all latency measures, with some pigs approaching and touching the ball immediately and some never approaching the ball. There was also a wide range in how often pigs crossed the lines and touched the ball.

Latency to the 1 m line was positively related to number of 24 h post-mix lesions on the front of the body but the relationship was weak (Slope = 0.001 lesions/s, SE = 0.0006, $F_{1,18}$=3.905, *P*=0.049). There were no other significant relationships between NOT variables and 24 h post-mix lesions. Results of the comparisons among 3 wk post-mix lesions and NOT variables are presented in Table 4.7. Pigs with more 3 wk post-mix lesions in the front of the body took longer to touch the novel object. Pigs with more 3 wk post-mix lesions in the middle of the body were quicker to cross the 0.5 m line but took longer to touch the ball, then touched the ball more often. Study replicate (24 h post-mix *P*>0.222; 3 wk post-mix *P*>0.095) and weight at mixing (24 h post-mix $P>0.182$; 3 wk post-mix $P>0.466$) did not have an effect on any NOT variables compared with lesion scores, but there was an effect of pre-mix lesion score (24 h post-mix $F_{1,18}>18.574$, $P<0.01$) and lesion observer for all NOT variables compared with 24 h post-mix ($F_{6,18}>3.894$, $P<0.01$) and 3 wk post-mix middle lesions ($F_{2,12}=4.519$, $P=0.018$), but not for 3 wk post-mix lesions in the front and rear ($P>0.607$).

Comparisons Between Tests

There were no significant linear relationships among response variables of the different behavior tests: latency to NO and the three HAT variables (r=-0.058, $P=0.987$); number of times approaching and touching NO with the three HAT variables (r=-0.031, $P=0.874$); latency to NO and handling scores (r=-0.009, $P=0.594$), number of approaches to and touches of NO with handling scores (r=-0.027, $P=0.806$); and both HAT variables and handling scores (r=0.005, $P=0.401$).

DISCUSSION

In this study, we compared a proxy measure of aggressiveness (skin lesion scores by body location) to three behavioral responses of finisher pigs including interaction with humans, response to handling, and reaction to novelty. We predicted that aggressive pigs, those with more 24 h and 3 wk front skin lesions (Turner et al. 2009; Desire et al. 2015), would be more interactive and intense with human observers in their home pens, easier to handle through a weigh crate, and quicker to approach and touch a novel object. We also predicted that pigs with few lesions, or pigs with more 24 h rear skin lesions and 3 wk post-mix rear lesions would interact less with human observers, be more difficult to handle through a weight crate, and be slower to approach and touch a novel object. Our results did not support our hypotheses.

Pigs with more front lesions 24 h post-mix had a longer latency to cross the 1 m line in the NOT. Tests comparing latency to approach a novel object and aggressiveness have generally found no relationship (Janczak et al. 2003; Brown et al. 2009; Tönepöhl et al. 2012). The relationship presented here was weak, therefore, the results should be treated with caution. Additionally, pigs with more 3 wk front post-mix lesions were less active in the weigh crate and took longer to make contact with the novel object. When comparing aggressiveness to handling score, D'Eath and colleagues (2009) found a weak, but significant, genetic correlation between higher aggressiveness (engaging in reciprocal fights and non-reciprocated aggression) and needing more assistance moving into the weigh crate. This was true at the pen level as well, where pigs from pens with high levels of aggression collectively needed more assistance entering and leaving the weigh crate (D'Eath et al. 2009). Together, these results imply that more aggressive pigs are less bold, active, and explorative when socially isolated in novel environments. Further work on how aggressive pigs respond to stressors when isolated versus in a group would be beneficial to understanding the implications of these results. Pigs with more 24 h post-mix rear lesions were more intense in their interactions with the human observer. Previous work by Desire and colleagues (2015) showed that 24 h post-mix rear lesions had lower correlations with observed behavior of that pig than 24 h post-mix front and middle lesions, suggesting that rear lesions may be less indicative of a pigs' own aggressiveness and may instead indicate the aggressiveness of its' pen-mates (Desire et al. 2015).

More 3 wk post-mix lesion scores can be an indicator of an unstable social group, where dominance relationships have to be repeatedly reestablished (Desire et al. 2015). Both handling scores and response to a novel object were related to more 3 wk post-mix lesion scores, suggesting that certain behavior types may be more prone to disrupting dominance relationships (Turner et al. 2009). Pigs with more 3 wk post-mix front lesions moved less in the weigh crate and took longer to touch the novel object. Previous work has suggested that pigs with more 3 wk post-mix front lesions may have been unaggressive at mixing but engaged in aggressive interactions afterwards to establish dominance relationships. Alternatively, these pigs may be individuals that are more aggressive in all social contexts, or high-ranking pigs that are being challenged by subordinates (Turner et al. 2017). Pigs with more 3 wk post-mix middle lesions crossed the 0.5m line quickly, took longer to make contact with the ball, but then touched the ball more often, suggesting a 'cautiously curious' animal. In a previous study, pigs with less aggressive behavior types were more likely to perform non-damaging aggressive behaviors or environmental exploration at mixing compared to aggressive individuals (Camerlink et al. 2016). Previous work has also showed less aggressive animals to have a longer latency to response to novelty, but then spend longer engaging with it. This pattern has been reported as part of the proactive-reactive theory of coping styles, which has been studied in pigs previously with varying results (Jessing et al. 1994; Forkman et al. 1995; Janczak et al. 2003). Further research into the personality of pigs that are prone to continually initiate aggression following mixing and the pigs that are prone to be the recipients of bullying may be useful in improving the welfare of group-housed pigs.

In this study, we used lesions as a proxy for aggressiveness in pigs. While lesions have been linked to aggressive behaviors both genetically and phenotypically (Turner et al. 2009; Desire et al. 2015), we would like to emphasize that lesions only provide an estimate of the aggressive behavior occurring in a pen. Direct observations are preferred for obtaining data on pigs' individual aggressiveness, but as in-depth observations are time consuming, it is not realistic for producers to perform such observations to monitor and manage group-housed pigs. Lesion counts are a possible, practical tool for producer as they can be obtained quickly and require no additional staff or tools. Future work will use direct observation from videos to explore the relationship between skin lesion counts and personality traits.

The 14 wk and 17 wk of age handling scores were not correlated with one another. At 14 wk of age, handling was a novel experience for the pigs, as they were brought to an unfamiliar area of the farm. Novel handling experiences have been shown to induce stress in pigs, and therefore the 14 wk of age handling score was considered a more accurate measure of behavior type (Forkman et al. 2007; Lewis et al. 2008). To assess the appropriateness of a behavior test in a species, Jensen et al. (1995) advised that behavior test results should be repeatable. However, consistent with our findings, studies that have assessed repeatability of tests throughout the lifetime of pigs have found a decrease in responsiveness, which can be attributed to habituation to the test situation and also to a general reduction in fear seen as animals mature (Janczak et al. 2003; Marchant -Forde et al. 2003; Brown et al. 2009; Scheffler et al. 2014).

As we expected aggressiveness to be related to measures of boldness, activity, and exploration, we predicted that there would be significant relationships between behavior tests. However, this was not the case in this study. This same pattern, or lack thereof, has been reported in many studies of pig behavior traits (Lawrence et al. 1991; Jensen 1995; Forkman et al. 1995; Spoolder et al. 1996; Tönepöhl et al. 2012; Scheffler et al. 2014). When studies have reported relationships between behavior tests in pigs, they have generally been weak or inconsistent across studies (van Erp-van der Kooij et al. 2002; Forkman et al. 2007; Brown et al. 2009). The tests in the present study were conducted differently, with two performed on isolated pigs, but with different challenges, and one performed in the group. Therefore, the responses measured in each test may be too different to be reasonably compared, and instead could be used in combination to generate a more complex behavioral profile for pigs (Forkman et al. 2007; Brown et al. 2009).

This study ended when the pigs were about 6 months old. It is possible that individual behavior types had not fully developed in these animals (Janczak et al. 2003; Dalmau et al. 2009). The pigs in this study were also housed in barren pens, and degree of environmental enrichment can alter behavioral responses in a variety of situations, including novel object tests, handling, and aggressiveness (Wemelsfelder et al. 2000; O'Connell et al. 2004; Bolhuis et al. 2005; Tönepöhl et al. 2012). Lack of home pen enrichment may have contributed to the pigs' intense behavior towards the observer in the HAT, as the pigs may have been highly motivated to chew and explore stockpersons' boots and pant legs. The present research used purebred Yorkshire pigs, which have been reported to be less reactive in load and scale tests compared to Landrace and Chester Whites but more reactive compared to Durocs (Yoder et al. 2011). Additionally, the tests used in this study were performed solely on castrated males. Behavioral assessments of animals from a single neutered sex may not be transferrable to intact males or to female pigs, although multiple studies have looked at sex differences using boars, gilts, and castrated males and found no effect (Jensen et al. 1995; Erhard et al. 1997; Forkman et al. 1995; Brown et al. 2009).

CONCLUSION

This study found several relationships between individual aggressiveness as measured by skin lesions, and a pigs' interaction with a human, response to handling, and response to novelty, as assessed by human approach, handling, and novel object tests, respectively. Aggressive pigs, as indicated by more 24 h post-mix front lesions, took longer to cross the 1m line in the novel object test. Aggressive pigs with more 3 wk post-mix front lesions were less active in the weight crate during the handling test and had a longer latency to touch the novel object. Pigs with more 24 h post-mix rear lesions were more intense in their interactions during the human approach test and pigs with more 3 wk post-mix middle lesions, were quick to cross the 0.5 m line, slow to touch the novel object, but subsequently touched the novel object more. Whether those pigs were less aggressive or simply aggressive in a different way is unclear at this time. Though the picture is complex, the results of this study suggest that individual aggressiveness is related to behavior in other social and non-social challenges, which implies that the wrong combinations of pigs in a group could potentially lead to prolonged aggression in the weeks following mixing. To address the issue of social aggression in group-housed pigs, further research is needed to fully understand the relationships between individual aggressiveness and other traits, so that we do not inadvertently breed pigs that are more reactive towards humans and novelty.

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APPENDIX

Table 4.1. *Timeline of when pigs were mixed into finisher pens, lesion scores and tests performed relative to age of pigs and weeks after being mixed.*

Age of pig (in weeks)	10	11	12	13	14	15	16	17
Weeks after mixing	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Lesion scoring	X			X				
Human approach test					X			
Novel object test								X
Handling test					X			X

Table 4.2. *Ethogram of behaviors recorded in the Human Approach Test (HAT).* The HAT was conducted on 257 barrows at 14 wk of age in their home pens. Behaviors were recorded using scan-sampling every 30 s for 9 min.

Behavior	**Description**
Not Interacting	Pig made no physical contact with observer.
Biting	Pig had an open mouth on part of observer and used moderate or low force as it closed its mouth on observer. The definition of moderate to low force was subjective for each observer, but typically was not associated with pain but may have included mild discomfort.
Intense Biting	Pig had an open mouth on part of observer and used extreme force as it closed its mouth on observer. The definition of extreme force was subjective for each observer, but typically included a sharp pain.
Nosing	Pig had a closed mouth and was touching its nose to the observer. The pig used moderate to low force with its nose as it interacted with observer. The definition of moderate to low force was subjective for each observer, but typically was not associated with pain but may have included mild discomfort.
Intense Nosing	Pig had a closed mouth and was touching its nose to the observer. The pig used extreme force with its nose as it interacted with observer. The definition of extreme force was subjective for each observer, but typically included acute pain.
Levering	Pig has its nose underneath or on the side of the observer's boot and used moderate to low force in an upward motion to lift up or move boot. Observer was able to remain in the same location.
Intense Levering	Pig had its nose underneath or on the side the observer's boot and used extreme force in an upward motion to lift the boot up, which forced the observer to physically move as the pig was performing the behavior.

Table 4.3. *Scoring system used for the Handling Test. Scoring* system was modified from D'Eath and colleagues (2009). The Handling Test was conducted on 257 barrows at 14 wk of age and 17 wk of age by moving single pigs through a chute and weigh crate and recording their behavior and the actions taken by the handler to successfully move the pig through the weigh crate.

Score	Description
Moving Into Crate	
1	Pig is standing firm at the entrance of the weigh crate and/or actively trying to escape or back up into handler. Pig is emitting high-pitched vocalizations and may be trying to jump over gates or over sorting board. Pig may require a break to calm down before attempting to re-weigh.
2	Pig is standing firm at the entrance of the weigh crate. Pig may have ears back and there might be grunting or squealing as handler touches pig. Handler is required to use moderate pushing or patting on the back to encourage pig to enter the weigh crate.
3	Pig may be passively standing at entrance; may be distracted by environmental stimuli; and requires some light touching on the back from the handler to enter the weigh crate.
4	Pig walks into weigh crate with no intervention from the handler, or is passively standing at the entrance of weight crate; may be distracted by environmental stimuli; and requires a wave of the hand in the line of vision to enter.
5	Pig runs forward into the crate without the handler's encouragement. Pig may be more than a foot ahead of handler as it comes into the chute and weigh crate.
In the Crate	
1	Pig is attempting to jump over sides of weigh crate or crash through the gates of the crate.
2	Pig moves forward and backward while in the weigh crate.
3	Pig stands still during weighing.
Leaving the Crate	
1	Pig is resistant to leaving weigh crate and is standing firm or trying to backup or jump over walls of crate. Pig requires moderate pushing or patting from handler to leave the crate.
2	Pig is resistant to leaving weigh crate but does so after light touching on the back from the handler.
3	Pig leaves of its own accord once the door is opened with no encouragement from handler.

Table 4.4. *Descriptive statistics for lesion scores.* Minimum, 1st quartile, mean (SE), median, 3rd quartile and maximum for the raw skin lesions score recorded immediately prior to mixing, 24 h post-mixing, and 3 wk post-mixing for 257 barrows in the grow-finish stage. Lesions (fresh, red marks on the skin) were recorded by body location including front, middle, and rear. Pre and 24 h post-mix lesions were scored when pigs were 10 wk old, while 3 wk post-mix lesion scoring occurred at 13 wk of age.

	Measure	**Min**	**1st Quartile**	**Mean (SE)**	**Median**	**3rd Quartile**	**Max**
Pre	Front	0	5	8.33 (0.29)	8	11	24
	Middle	0	6	11.26 (0.43)	10	15	38
	Rear	0	4	6.67 (0.25)	6	9	22
24 h post-mix	Front	0	27	49.68 (1.81_	46	71	135
	Middle	1	20	42.11(1.82)	35	59	162
	Rear	0	12	22.94 (0.96)	22	32	145
3 wk post-mix	Front	0	2	5.28 (0.38)	4	7	69
	Middle	0	1	4.79 (0.34)	3	6	32
	Rear	0	0	2.55 (0.21)	2	4	35

Table 4.5. *Descriptive statistics for human approach and novel object tests.* Minimum, 1st quartile, mean (SE), median, 3rd quartile and maximum for the responses during the Human Approach Test (HAT) and Novel Object Test (NOT) for 257 barrows in the grow-finish stage. HAT was conducted at 14 wk of age in home pens, where number and severity of interaction with human observer was recorded every 30 s for 9 min. NI indicates “neutral interactions;” the percentage of times the pigs spent interacting using low/moderate oronasal contact with human observer. II indicates “intense interactions;” the total number of times the pig used extreme oronasal contact with human observer. AI indicates “all interaction;” the total number of times the pigs spent in oronasal contact with the human observer. NOT was conducted at 17 wk of age in a novel arena. Pigs were given a 1 m acclimation period followed by a 5 min exposure to a basketball.

	Measure	**Min**	**1st Quartile**	**Mean (SE)**	**Median**	**3rd Quartile**	**Max**
HAT	NI	0%	17%	35%(0.01)	33%	50%	89%
	II	0%	0%	7%(0.01)	0%	11%	56%
	AI	0%	22%	42% (0.01)	39%	56%	94%
NOT	Latency to 1m (s)	0	5	43.62 (3.74)	22	54	301
	Latency to 0.5m (s)	0	9	66.80 (4.97)	36	92	301
	Latency to Touch (s)	1	15	90.84 (5.88)	55	135	301
	Freq. 1m line crosses	0	3	4.75 (0.13)	5	6	13
	Freq. 0.5m line crosses	0	3	3.99 (0.13)	4	5	12
	Freq. NO touches	0	3	5.10 (0.20)	5	7	16

Figure 4.1. *Distribution of scores for reactions during the Handling Test for 257 barrows.* The Handling Test was conducted at 14 wk of age and 17 wk of age by moving pigs individually through a weigh crate and recording their responses using a scoring system described in Table 3. Low scores indicate a less cooperative pig, while high scores indicate a more cooperative pig.

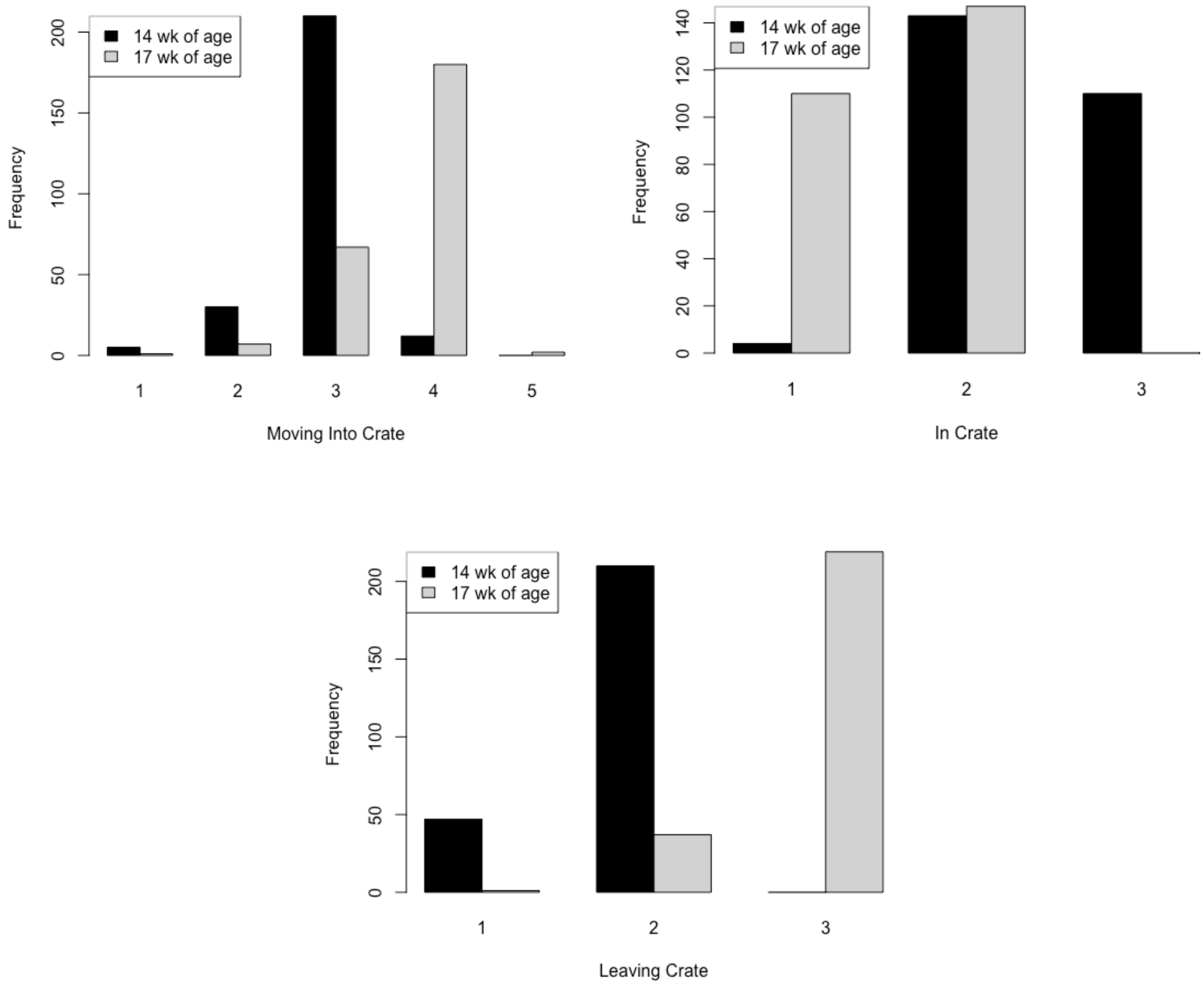

Table 4.6. *Handling Test scores compared to 3 wk post-mix lesion score by body location*. Low handling test scores indicate a less cooperative pig, while high scores indicate a more cooperative pig. Bold text indicates *P*<0.05.

	3 wk Post-Mix Front Lesions			**3 wk Post-Mix Middle Lesions**			**3 wk Post-Mix Rear Lesions**		
	Intercept	SE	*P*	Intercept	SE	*P*	Intercept	SE	*P*
Enter: Score 3	-0.077	0.159	-0.628	-0.083	0.169	0.624	-0.016	0.153	0.917
Enter: Score 4	-0.088	0.151	0.559	-0.065	0.16	0.687	-0.007	0.146	0.962
Enter: Score 5	-0.118	0.179	0.512	-0.109	0.189	0.567	-0.029	0.173	0.864
In: Score 2	**0.347**	**0.169**	**0.041**	0.135	0.179	0.454	0.147	0.164	0.371
In: Score 3	**0.407**	**0.174**	**0.021**	0.185	0.185	0.319	0.129	0.169	0.444
Leave: Score 3	0.054	0.057	0.339	-0.005	0.059	0.927	-0.012	0.055	0.825

Table 4.7. *Novel object test variables compared to 3 wk post-mix lesion score by body location*. 257 barrows were given a 1 min acclimation period followed by a 5 min exposure to a novel object (basketball) and recorded for latency to approach and touch the object, and for number of times approaching and touching the object. Bold text indicates $P<0.05$.

	3 wk Post-Mix Front				**3 wk Post-Mix Middle**				**3 wk Post-Mix Rear**			
	Intercept	SE	$F_{(1, 18)}$	*P*	Intercept	SE	$F_{(1,18)}$	*P*	Intercept	SE	$F_{(1,18)}$	*P*
Latency to 1 m	0.0001	0.001	0.014	0.906	0.001	0.001	3.253	0.073	0.001	0.001	0.649	0.421
Latency to 0.5 m	-0.001	0.001	1.429	0.233	**-0.002**	**0.001**	**7.949**	**0.005**	-0.001	0.001	1.031	0.311
Latency to Touch	**0.001**	**0.0004**	**4.609**	**0.033**	**0.001**	**0.0004**	**7.679**	**0.006**	0.0003	0.0004	0.878	0.349
#1 m Crosses	-0.009	0.018	0.245	0.621	-0.006	0.018	0.114	0.736	0.002	0.017	0.019	0.890
#0.5 m Crosses	-0.008	0.021	0.134	0.715	-0.005	0.022	0.054	0.817	-0.001	0.021	0.004	0.952
# Touches	0.017	0.009	3.376	0.067	**0.019**	**0.003**	**3.887**	**0.049**	0.016	0.009	3.117	0.079

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CHAPTER 5: AFFILIATIVE AND AGONISTIC BEHAVIOR IN GROUP-HOUSED FINISHER PIGS

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ABSTRACT

Agonistic behavior in group-housed pigs is a major welfare concern. Previously efforts have focused on finding ways of reducing aggression, but as pigs are highly social animals, having a better understanding of how pigs promote and maintain social relationships would also be beneficial to pig producers. This study aimed to investigate potentially affiliative behaviors in group-housed pigs, how these behaviors changed over time and their relationship to agonistic behaviors, and the effect of moving to a new pen on these behaviors. A total of 65 purebred Yorkshire barrows (castrated males) were observed for agonistic and affiliative behaviors immediately after mix into grow-finish pens (10 wk of age, ~23 kg), and wk 3, 6, and 9 after mix. At wk 6, pigs were moved to a new pen with their same social group. The affiliative behaviors being investigated were duration of nosing (s) and play (s), proportion of time spent in physical contact with conspecifics without overt aggression. The agonistic behaviors were duration of total aggression (s) and duration of initiated aggression (s). Affiliative behaviors were compared across time points using least square means. The relationships between affiliative and agonistic behaviors were assessed using generalized linear mixed models. Affiliative contact with conspecifics increased between mix and wk 3 (P<0.01), and between wk 3 and wk 6 (P=0.015) but remained stable between wk 6 and wk 9 (P=0.954), suggesting pigs took up to 6 wk to settle into their new social group. Nosing occurred at the same rate between mix and wk 3 (P=0.999), was lower in wk 6 (P<0.01) but remained stable between wk 6 and wk 9 (P=0.109). Play was highest at wk 3 and wk 9 and occurred at a similar rate at both time points (P=0.289); there was little play at mix and wk 6 (P=0.997). Affiliative contact with conspecifics at mix was negatively related to agonistic behavior at mix ($P<0.005$). Nosing at wk 9 was associated with increased aggression at wk 9 ($P<0.039$). Duration of play at mix was related to increased aggression wk 6 after mixing ($P=0.004$). There were no obvious effects of moving established social groups to a new pen. There appear to be relationships between affiliative and agonistic behaviors in pigs, with affiliative contact being the most predictive of less aggression. Future studies should focus on how to promote affiliative contact in unfamiliar pigs.

INTRODUCTION

Within the pig industry, group housing provides a number of benefits to pigs such as increased space allowance per pig, the ability to perform more natural behaviors, and interaction with conspecifics. However, group housing also presents major welfare concerns, most notably, social aggression when pigs are mixed into new social groups. Management interventions available to producers to address this issue do not successfully mitigate aggression altogether, but rather just delay the onset of aggression (Marchant-Forde and Marchant-Forde, 2005; Peden et al., 2018). Recent research has focused on finding a genetic component of social aggression to allow producers to breed pigs more suitable for group housing systems (Turner et al., 2010). However, little research examined what successful group housing looks like, particularly in regard to affiliative behaviors in pigs. Having a better understanding of how pigs display affiliative behavior and use it to form stable social groups could allow breeding programs to reduce social aggression by breeding pigs that are more social, and able to read and respond to social cues.

In commercial pig production, pigs are often mixed at different production stages based on sex and weight (Turner et al., 2010). Mixing of unfamiliar pigs leads to high levels of aggression as pigs fight to establish a social hierarchy. Increased aggression can occur for up to

48 hours after a mixing event (Meese and Ewbank, 1973). In some social groups, higher levels of aggression are seen after this initial time period causing chronic social stress which can have prolonged negative effects on pig welfare, including disruptions to growth and immune function (Turner et al., 2013).

Studies of pig social behavior have primarily focused on aggression, but pigs, like all gregarious species have a wide range of behaviors that are meant to promote strong social bonds. Spatial integration, gentle nosing, and play have previously been studied as possible affiliative behaviors in pig social groups (Erhard et al., 1997; Turner et al., 2013; Camerlink et al., 2014). However, evidence on which behaviors are truly affiliative, in that they will promote positive social interactions and stable social groups, have not been well studied in pigs (Camerlink et al., 2014). Understanding the full range of behaviors pigs exhibit while integrating into new social groups is important for producers and researchers. Identifying affiliative behaviors that are positive indicators of social stability could provide producers a way to intervene as needed to prevent loss and breed pigs that can thrive in commercial group-housing.

The objectives of this research were to quantify potentially affiliative behaviors in group-housed finisher pigs including play, nosing, and spatial proximity to conspecifics at 4 time points after mixing including after pigs were moved to a new pen to investigate the effects of a minor change in environment on affiliative and agonistic behaviors, and to compare measures of affiliation to levels of aggression in recently mixed and stable social groups. The hypotheses were that pigs would display more affiliative behavior in stable social groups, particularly when introduced to a new pen, and that displaying more affiliative behaviors would result in less agonistic behavior.

MATERIALS AND METHODS

The Michigan State University Institutional Animal Care and Use Committee approved all procedures (Animal Use Form number 01/14-003-00).

Animals and housing

All animals included in this study were housed at the Michigan State University Swine Teaching and Research Center in East Lansing, MI, USA. A total of 65 purebred Yorkshire barrows (castrated males) across 5 pens were observed starting at 10 weeks of age (approximately 23 kg) when they were mixed into new groups in finisher pens (4.83 m x 2.44 m). A commercially formulated diet specific to the nutritional requirements of pigs at that production stage was provided. Pigs could eat *ad libitum* (NRC, 2012) from self-feeders with no more than 10 pigs per space. Pigs also had *ad libitum* access to water from nipple in cup drinkers, with one drinker available in each pen. The pigs received full incandescent light for 8 h per day, and half-light from auxiliary incandescent bulbs for 16 h per day.

To create the new groups, pigs were mixed into same sex groups with pigs of similar weight. The new social groups consisted of 3-5 groups of pigs from different nursery pens for a total of 10-15 pigs per finisher pen. Thus, each pig was mixed with 2-5 familiar pigs from their nursery pen and 10-13 pigs that were unfamiliar. To test the effects of a new pen on affiliative behavior, pigs were moved to a similar but unfamiliar pen 6 wk after mix. Pigs remained in this pen until the end of the study. The new pens were in the same room and had the same resources as their original pen, and they were housed with the same social group. Pigs were moved into new pens at random.

Behavioral observations

Behavioral observations were conducted immediately after mixing at 10 weeks of age, then at 3, 6, and 9 weeks after mixing when groups are typically considered relatively stable. Observations were made using video recorded by a ceiling-mounted camera (Clinton Electronics VF540 Bullet Cameras) above each pen that was connected to a digital video recorder (Geovision 1480A).

For identification purposes, the back of each pig was marked with a unique number using a non-toxic permanent marker. Pigs were observed using all-occurrence sampling (Altmann 1974) for 4 consecutive hours in the afternoon at each of the 4 time points (mix, 3, 6, and 9 wk after mix) to capture duration (s) of affiliative and aggressive behaviors including play behaviors (scamper, pivot, head toss, flop, and paw from the ethogram reported in Donaldson et al., 2002), nosing (defined as any interaction where a pig touches its nose to a conspecific), and aggressive behaviors (reciprocal fights, attacks, head knocks, and presses). Pigs were also observed for their proximity to conspecifics using scan-sampling (Altmann 1974) every 10 min, recording the proportion of time pigs were in physical contact with a conspecific without displaying overt aggressive behavior.

Statistical analysis of results

Data analyses were completed using R (Version 1.0.136, R Core Team 2016; Vienna, Austria). Packages used include: xlsx (Dragulescu & Arendt, 2018), psych (Revelle 2017), lmerTest (Kuznetsova et al., 2017), car (Fox & Weisberg, 2011) and lsmeans (Lenth, 2016).

Affiliative behaviors were compared across time points using least square means with period as a fixed effect and pen as a random effect. Tukey's HSD test was used to obtain adjusted *P*-values. All variables were assessed for normality by visual inspection of Q.Q. plots.

Duration of nosing (s) and duration of play (s) were transformed for normality using a $\log_{10}+1$ transformation. Proportion of time spent in physical contact with conspecifics was transformed for normality using an arcsine square root transformation. Aggression (s) was transformed for normality using a $\log_{10}+1$ transformation.

Agonistic behaviors were summarized into total duration of aggression (s) and total duration of initiated aggression (s) for each time point. Affiliative behaviors were compared to agonistic behaviors using generalized linear mixed models fitted for each agonistic measure (duration of total aggression and initiated aggression) and each time period (mix and 3, 6, 9 wk after mix). Models were also fitted to test the effects of affiliative behaviors performed at mix with aggression occurring at each of the later time points. The models included the affiliative behaviors of play, nosing (scaled prior to analysis due to differences in the scales of the measurements for nosing, play, and social contact, and due to the vast differences between duration of nosing and play), and social contact as fixed effects, and pen as random effect.

RESULTS

Quantifying affiliative behaviors across time and when moved to a new pen

The least square means of social contact, nosing, and play, as well as the comparisons of each behavior across time points are presented in Figure 5.1. Pigs spent more time in physical contact with conspecifics at later time points than immediately after mixing, with time spent in physical contact remaining the same between wk 6 and wk 9 after mixing. Pigs spent the most time nosing immediately after mixing and at wk 3. Nosing occurred for less time at wk 6 and wk 9 after mixing but remained stable between these two time points. The least time spent playing occurred immediately after mixing and when pigs were moved to a new pen wk 6 after mixing.

Similar durations of play were seen at wk 3 and wk 9. There was no effect of moving pigs to a novel pen on affiliative or agonistic behaviors.

Comparisons between affiliative and agonistic behaviors

The relationships between affiliative and agonistic behaviors at mix, wk 3, wk 6, and wk 9 are presented in Table 5.1. Pigs showing more aggression and those spending more time initiating aggression at mixing were less likely to be in affiliative physical contact with conspecifics at mixing. This pattern was also seen between affiliative physical contact at wk 6 and pigs initiating aggression at wk 6, but this relationship was weak. Pigs showing more aggressive behaviors at wk 9, including those initiating aggression, spent more time nosing at this time period as well.

The relationships between affiliative behaviors shown immediately after mix and levels of aggression at wk 3, wk 6, and wk 9 after mixing were also investigated. Pigs that spent more time playing immediately after mix spent more time in aggressive interactions at wk 6 (Estimate: 0.167, SE: 0.053, $F_{(1,4)}$=8.797, P=0.004), but not in total initiated interactions (P>0.110). There were no other relationships among affiliative behaviors at mix and agonistic behaviors during stable time points (P>0.085).

DISCUSSION

Efforts to address the welfare concerns present in group-housed pigs due to social aggression have mainly focused on reducing agonistic interactions but social animals display a wide range of behaviors to promote social bonds. Having a better understanding of affiliative behaviors in pigs may help producers and researchers identify and implement behavioral management techniques that not only reduce agonistic behaviors, but also promote affiliative behaviors and positive welfare. The objectives of this study were to quantify potentially affiliative behaviors in group-housed finisher pigs at 4 time points following a mixing event and to compare these affiliative behaviors to levels of agonistic behaviors. We also aimed to investigate the effects of a minor stressor, moving pigs to a new pen, on affiliative and agonistic behaviors. The hypotheses of this study were that pigs would display more affiliative behavior in stable social groups, particularly when introduced to a new pen, and that displaying more affiliative behaviors would show less agonistic behavior.

Quantifying affiliative behaviors across time

The affiliative behaviors investigated in this study were social contact, nosing, and play. The proportion of time pigs spent in affiliative social contact with conspecifics increased throughout the study period before stabilizing between wk 6 and wk 9 after mixing. Body contact or proximity to conspecifics has been used as a measure of affiliation in social animals, as animals tend to stay in close proximity with familiar or preferred conspecifics (Camerlink et al., 2014), and it may take months for pigs to fully spatially integrate into new social groups (Turner et al., 2013). Immediately after a mixing event, pigs remain in affiliative physical contact with familiar pigs over unfamiliar pigs, demonstrating that they preferentially associate with some pigs more than others in positive ways. On the day of mixing, 53% of the dyads of familiar pigs showed preferential associations, while only 9% of unfamiliar pigs showed preferential associations. However, 3 days after mixing, preferential associations between familiar and unfamiliar pigs were similar at 20% and 18%, respectively (O'Malley et al., 2018). The results of our study and previous studies suggest that affiliative physical contact, proximity to conspecifics, and spatial integration may be a valid method measure of affiliation in pigs.

Pigs spent a lot of time nosing at all time points following mixing but was highest at mixing and 3 wk after. Time spent nosing dropped in wk 6 then remained stable through wk 9.

The motivation behind nosing between pigs is not well understood, but it has been proposed that nosing could be a form of affiliative behavior. Camerlink et al. (2012) found a positive link between growth rate and pigs that receive nosing, suggesting a potential link between nosing and social dominance. However, these results were not supported by Camerlink et al. (2013). In that study, there were no clear benefits or motivation found for giving or receiving nosing behavior on dominance relationships, and in the present study we saw a similar pattern, where most interactions between pigs were preceded by or followed by nosing. It has been suggested that nosing is a way for pigs to detect cues from their environment and is used in social recognition and communication (Camerlink et al., 2013; Horback, 2014). There are also instances where nosing in pigs can be considered to be a harmful behavior, for example when it leads to belly nosing, and tail or ear biting (Camerlink et al., 2013). In the present study, distinguishing between affiliative nosing and harmful nosing was not always possible. For example, some incidences of nosing were long in duration and directed at the belly or ear, especially in the stable time points, and could have been a form of stereotypic or harmful oro-nasal behavior (Camerlink et al., 2013). Few studies have investigated nosing. The results of these studies are ambiguous and provide few insights into the role of nosing in promoting positive social interactions and stable social relationships in pigs.

Pigs spent little time playing immediately after mix and at wk 6, but similar amounts of time spent playing were seen at wk 3 wk and 9. Play is often seen in juvenile animals and is thought to be important in the development of behavioral and physical skills needed as an adult (Martin et al., 2015). Play is often used as a measure of positive affective states in animals, with stressful situations typically causing a decrease in the frequency of play (Ahloy-Dallaire et al., 2018). Mixing is known to be stressful for pigs, so the low amount of time spent playing at that time point is in line with play as an indicator of welfare. However, this does not explain why play was similarly low at wk 6 (except for the effect of the novel pen, which will be discussed below). The peak ages for play in pigs occur between 2 to 6 wk of age (Newberry et al., 1998; Horback, 2014). The pigs in this study were 10 to 19 wk of age, which may explain the low occurrence of play. However, introducing pigs to novel or bigger environments elicits play behavior in pigs older than 6 wk, and even in sows (Horback, 2014). The barren environment the animals were housed in might also have contributed to the low occurrence of play recorded in this study (Horback, 2014). In this study, we also only recorded locomotor play, as social play can be difficult to distinguish from aggression on video recordings. Few studies have investigated play in pigs and those that have often focus on pigs younger than 4 wk of age. Future studies exploring social play in group-housed pigs may provide insight about positive social relationships.

The effect of a novel pen on affiliative behaviors

There was no consistent change in affiliative behaviors when established groups of pigs were moved to a new pen. There was an increase in affiliative physical contact seen between wk 3 and wk 6 after a mixing event. However, as the amount of affiliative contact remained the same between wk 6 and wk 9, this increase was not likely due to being moved to a new pen at wk 6. Pigs can take multiple weeks to settle into a new environment, and there can be elevated levels of aggression for at least 3 weeks following a mixing event (Turner et al., 2013). It could be possible that the increase in time spent in affiliative contact between wk 3 and wk 6, and the consistency in affiliative contact between wk 6 and wk 9, show that pigs had formed a stable social group by wk 6.

There was a decrease in time spent nosing between wk 3 and wk 6, but similarly to affiliative contact, the amount of time spent nosing remained the same between wk 6 and wk 9, so it is likely not a result of the novel pen but might be a result of pigs settling into the environment. If nosing is an affiliative behavior used for social recognition and communication as suggested by Camerlink et al. (2013), then nosing would be predicted to increase at wk 6 as pigs adjust to a novel pen. This did not appear to be the case in this study. Pigs in this study were housed in a barren pen with no enrichment. At wk 9, nosing was positively related to duration of total aggression and duration of initiated aggression. As mentioned previously, distinguishing between affiliative nosing or harmful nosing was difficult. Therefore, it is possible that nosing was a form of stereotypic or displaced exploratory behavior (Camerlink et al., 2013) that led to increased aggression because pigs were disturbing their penmates.

Time spent playing was similarly low after mix and at wk 6 but were at the same increased level at wk 3 and wk 9. This could suggest that stressors, even minor ones such as movement to a novel pen could cause a decrease play behavior (Ahloy-Dallaire et al., 2018). However, there is no other evidence suggesting that being moved to a new pen had any positive or negative effects on the pigs in this study, so these results should be interpreted with caution.

Comparisons between affiliative and agonistic behaviors

Pigs in affiliative physical contact with conspecifics spent less time performing aggression and initiating aggression at mix. When pigs are mixed into a new social group, they will remain close to familiar pigs for at least the first 24 h and will mainly display agonistic behaviors towards unfamiliar pigs as they work to establish social relationships (Camerlink et al., 2014). This would explain why pigs remaining in affiliative contact with conspecifics would spend less time in agonistic interactions following mixing. Other pigs, however, may engage in aggression with unfamiliar pigs. Camerlink et al. (2014) did not find a relationship between aggression and social proximity of pigs. However, they did not parse out differences between total or initiated aggressive interactions and were looking specifically at actual distances between pigs, not proportion of time spent in affiliative physical contact with conspecifics.

Affiliative behaviors displayed after mixing largely had no predictive value on the duration of aggression at the stable time points, with the exception of a relationship between pigs that spent more time playing at mix spending more time in agonistic interactions 6 wk later. This was not true for initiated aggression, which could suggest the pigs that show this relationship are on the receiving end of agonistic behavior. It has been suggested that pigs that do not participate in agonistic behavior at mix are more likely to be the recipients of aggression in the weeks after mixing because these pigs did not establish their place in the social hierarchy (Turner et al., 2017). While it is generally assumed that play occurs in the absence of stress (Horback, 2014), more recent evidence suggests that play can also act as a coping mechanism for individuals in stressful conditions (Ahloy-Dallaire et al., 2018). The presence of play after mixing may be a coping mechanism for pigs avoiding agonistic interactions, thus causing them to be the target of aggressive interactions 6 wk after mixing (which also coincided with when pigs in this study were moved to a new pen), but this connection needs to be investigated further.

CONCLUSION

The objectives of this study were to quantify potentially affiliative behaviors in group-housed pigs and how these behaviors might change over the weeks following a mixing event and in response to being moved to a new pen and to assess the relationship between affiliative and agonistic behaviors. Affiliative social contact, nosing, and play did change in the weeks following a mixing event, with pigs spending more time in affiliative contact with conspecifics as time passed after a mixing event, nosing more in the first 3 wk after mixing than at later time points, and playing most in wk 3 and wk 9 after mixing. There appeared to be no effects of moving pigs to a novel pen on affiliative behavior. There were few predictive relationships between affiliative and agonistic behaviors. However, affiliative contact at mixing and at wk 6 was negatively related to aggression and nosing at wk 9 was associated with more aggression. The results of this study suggest that affiliative contact could be an indicator of positive social relationships and stability but the role of nosing and play in affiliation are less clear.

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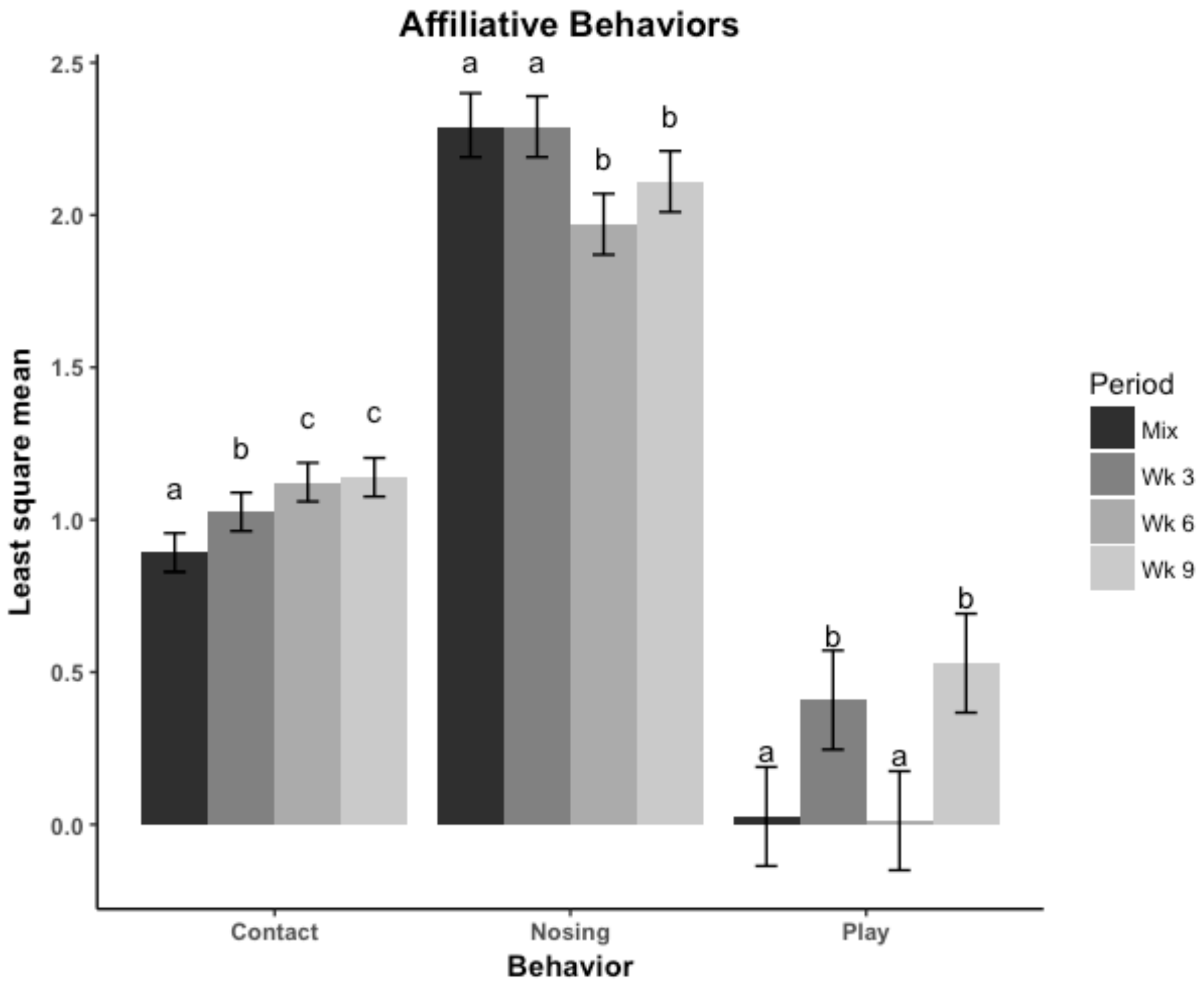
APPENDIX

Table 5.1. *Comparison of affiliative and agonistic behaviors.* Affiliative behaviors of social contact (proportion of time in contact with conspecific without overt aggression), duration of nosing (s), and duration of play (s) were compared to total duration of aggression (s) and total duration of initiated aggression (s) at 4 time points: immediately after mixing, and 3, 6, and 9 wk after mixing. Comparisons were made using linear mixed models. * indicates P<0.05.

			Slope	**SE**	$\mathbf{F_{(1, 4)}}$	***P***
Total aggression (s)	**Mix**	Contact	-1.459	0.323	18.999	0.0001*
		Nosing	-0.095	0.062	2.231	0.141
		Play	0.024	0.045	0.270	0.605
	3 wk	Contact	-0.108	0.243	0.177	0.676
		Nosing	0.041	0.040	0.977	0.327
		Play	0.005	0.005	1.128	0.293
	6 wk	Contact	-0.770	0.448	2.729	0.104
		Nosing	0.120	0.067	2.879	0.095
		Play	0.019	0.118	0.024	0.877
	9 wk	Contact	-0.278	0.373	0.507	0.479
		Nosing	0.107	0.047	4.997	0.029*
		Play	0.001	0.004	0.082	0.775
Total initiated aggression (s)	**Mix**	Contact	-0.943	0.302	8.679	0.005*
		Nosing	-0.075	0.059	1.487	0.227
		Play	0.039	0.043	0.781	0.381
	3 wk	Contact	-0.069	0.279	0.058	0.811
		Nosing	0.043	0.046	0.818	0.369
		Play	0.006	0.005	1.086	0.302
	6 wk	Contact	-0.992	0.476	4.029	0.049*
		Nosing	0.069	0.071	0.831	0.366
		Play	0.083	0.125	0.417	0.521
	9 wk	Contact	-0.381	0.375	0.946	0.335
		Nosing	0.101	0.047	4.463	0.039*
		Play	-0.005	0.004	1.508	0.224

Figure 5.1. *Affiliative behaviors were compared across 4 time points using least square means regression analysis.* The 4 time points include: immediately after mix, and 3, 6, 9 wk after mix. Social contact is presented as proportion of time pigs spent in physical contact with conspecifics without overt aggression. Nosing and play is presented as duration (s) of each behavior. Errors bars represent the 95% confidence interval of the least square means. Bars with the same letter denote time periods that showed similar occurrences of that behavior ($P < 0.05$, Tukey, HSD adjusted).



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CHAPTER 6: GENERAL DISCUSSION AND CONCLUSION

Over the past several years, consumers have become more concerned over the welfare of our production animals (Ochs et al., 2018). One issue that is particularly concerning to consumers is the practice of housing sows in gestation crates, expressing concerns over the animals' inability to perform natural behaviors (Thorslund et al., 2017). In response to these concerns, over 60 food companies have promised to purchase only "crate-free" pork products, and ten states have passed legislation stating pig producers have to phase out gestation crates by a certain deadline (Tonsor et al., 2009a; Andrews, 2014). The alternative housing system to gestation crates is group housing. While group housing does address some of the concerns from consumers, it presents a different set of welfare problems. Pigs at other production phases, such as grow-finish, are already group-housed and producers face challenges in managing these systems. Under group-housing systems, pigs are often housed with pigs of the same sex and weight which can cause intense aggression as unfamiliar pigs establish social relationships (Turner et al., 2010). A number of solutions have been implemented to mitigate the aggression, but most are unsuccessful.

There is ongoing need for research investigating new solutions to address this issue. The research presented here aimed to address this issue by investigating the role of animal personality and social behaviors on the management and welfare of group-housed pigs. The long-term goals of this project were to identify the individual behavior types exhibited by domestic pigs, and to explore the role of individual behavior on social cohesion in recently mixed pigs. The objectives of this research were to understand the role of personality in the management and welfare of pigs, identify individual behavior types using individual time budgets and behaviors tests, and explore measures of social cohesion in recently mixed pigs as they form stable social groups.

For chapter 2, an in-depth review of the literature on pig personality was conducted with a goal to guide management practices for pig producers. Over 80 peer-reviewed articles were reviewed for methodology and findings in relation to pig management and welfare. These papers had a wide variety of objectives including comparing behavioral responses across situations to identify personality types, relating personality traits to physiological parameters, looking at how personality influences behaviors such as tail biting or social aggression, and testing the consistency of the behavior tests used to measure personality, to name a few. Personality traits were found to be related to physiology, housing, social behavior and cognition. However, the study of personality in applied ethology is a relatively new field, resulting in a number of issues and inconsistencies across the literature. Moving forward, a clear framework on studying personality in pigs is needed, and effort needs to be put into testing the reliability and validity of personality assessment methods. Due to the vast number of papers on personality, this literature review had strict guidelines for inclusion. No studies investigating only a single personality trait was used in this review, thus limiting the scope of the review and its impacts on pig management, particularly as it relates to social aggression.

In chapter 3 individual variation in behavior was compared across multiple time points after a mixing event to get a better understanding of pig behavior in a commercial facility. Pigs' behavior continued to change until about 6 weeks after mixing, then remained mostly stable through week 9. This has practical applications to management as it suggests that pigs can take up to 6 weeks to adjust to a new environment and social group. Aggression occurring up to 3 weeks after mixing was related to pigs' non-aggressive behavior and negatively impacted growth rate and loin muscle area. When pig producers have implemented interventions to mitigate aggression, most of the time it occurs immediately after mixing. These results suggest that aggression occurring even 3 weeks after mixing can disrupt productivity, and therefore behavioral management techniques should be implemented within the first 3 weeks to decrease aggression. A major limitation to this study is the time-consuming nature of video decoding. Pigs were observed for 4 hours in the afternoon. Observing the pigs in the morning may yield different results or show more variation in behavior.

If producers wish to breed for pigs that are less aggressive, it is important to understand the implications this may have on other behavior traits. In Chapter 4, we used behavior tests to measure personality traits of fearfulness and response to humans. In this test we compared pigs' response to a novel object test, human approach test, and handling test to skin lesions, a proxy measure for aggressiveness. The results of this study showed there are relationships between aggressiveness and other behavior traits, and these breeding for less aggressive pigs could have unexpected consequences. Many of the relationships found were between variables measured in the novel object and handling tests and skin lesion counts taken at 3 weeks after mixing. This may indicate that lesion counts taken at more stable time points are more indicative of personality type than lesions taken at mix.

Our goal for Chapter 5 was to gain a better understanding on affiliative behaviors and how they may relate to aggression. Identifying positive social behaviors could be beneficial to breeding programs. Pigs were observed for nosing, play, and affiliative social contact. Affiliative behavior changed over time after a mixing event with nosing highest in the first 3 weeks after mixing, play highest 3 and 9 weeks after mixing, and social contact highest at weeks 6 and 9. Social contact was the best predictor of aggression. Understanding affiliative behaviors is important for promoting positive welfare and stable social groups. This study was limited by the lack of knowledge on affiliative behaviors in pigs.

For this project, we aimed to gain a better understanding of how individual behavior can influence social aggression in pigs. Only castrated male pigs were used in this study, which presents limitations in the results but as the animals were pre-pubertal, we think that the results could be useful in other populations as well. The results of these studies suggest that individual personality traits are important in the welfare and management of pigs, and that learning more about pig's behavior, particularly their positive social behaviors, could help us reduce aggression and breed for pigs better suited for group-housing.

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