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Demand driven solutions to reduce aggression between pigs

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Doctor of Philosophy*

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I dedicate this thesis to my parents for all of their encouragement and support.

Signed Declaration

I declare that the thesis has been composed by myself and that the work has not been submitted for any other degree or professional qualification. I confirm that the work submitted is entirely my own, except where jointly-authored publications have been included. My contribution and those of the other authors to this work are clearly outlined below and throughout this thesis. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

The work presented in Chapter 2 was previously published in *Applied Animal Behaviour Science* by the author of the declaration, and Irene Camerlink, Simon Turner, and Laura Boyle. Two supervisors (Simon Turner and Irene Camerlink) were co-authors. Rachel Peden conducted the review of the academic literature and produced the first full draft of the manuscript. Irene Camerlink, Simon Turner and Laura Boyle all provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to

external peer review comments, prepared the response letter for the journal and was the corresponding author.

The work presented in Chapter 3 was previously published in *Anthrozoos* by the author of the declaration, and Simon Turner, Faical Akaichi, Irene Camerlink, Steve Loughnan and Laura Boyle. Three supervisors (Simon Turner, Faical Akaichi and Irene Camerlink) were co-authors. Rachel Peden designed this study, collected data, analysed data and wrote the original version of the manuscript. Simon Turner and Laura Boyle helped to collect data at farmer discussion groups. Simon Turner provided advice on appropriate statistical analysis. Simon Turner, Faical Akaichi, Irene Camerlink, Steve Loughnan and Laura Boyle provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to external peer review comments, prepared the response letter for the journal and was the corresponding author.

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Signature:

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Lay Summary

Unfamiliar pigs are regularly regrouped in commercial pig farming and this causes high levels of physical aggression as animals establish dominance relationships. Animal scientists have researched this behaviour extensively since the 1970s and have identified several management strategies to reduce the occurrence or intensity of aggressive behaviour. However, these strategies are not commonly used by farmers in commercial practice, and aggression remains an important problem for animal welfare and farm productivity. This project provides the first investigation into the social and economic factors which influence farmers' behaviour regarding aggression. At various stages of this project farmers perceptions of pig aggression and welfare were compared to other stakeholder groups in order to establish the impact of farmers' role and experience. Comparison groups had experience of working with pigs but in a different context (specialised pig veterinarians); had knowledge of agriculture and livestock but no experience of working with pigs (agriculture students and animal science students); and were removed from animal production (citizens unrelated to agriculture).

The first aim of this project was to understand the behaviour of UK and Irish pig farmers with regards to aggression between pigs. This was important

because understanding behaviour, and the contexts in which it occurs, is essential for identifying targets for initiating a change in practice. In order to meet this aim, three survey studies were carried out. The first study obtained evidence for widespread belief in pigs' capacity to suffer amongst farmers and non-farmers. Therefore, the limited uptake of aggression research in practice was not related to a lack of belief in the capacity of pigs' to experience suffering. Nevertheless, it remained unclear whether farmers perceive aggression as a source of pig suffering. The results of the second study indicated that farmers (and non-farmers) were inefficient at recognising the severity of injuries as a result of aggression when they saw pigs after the fight had ended, and did not see the fight occurring. Farmers are unlikely to see fights on their farm as frequently as they actually occur; therefore farmers need to better recognise these injuries. However, recognition of the issue alone is unlikely to be sufficient to change farmers' behaviour. In the third study, an in-depth analysis of the wide range of factors likely to influence farmers' behaviour revealed that a range of interrelated factors were important. Specifically, farmers' willingness to reduce aggression was influenced by: 1) whether they felt able to implement the change on their farm, 2) beliefs about the likely consequences, 3) perceptions of aggression as a problem on their farm, and 4) the opinion of

relevant stakeholder groups, with the opinion of veterinarians being particularly important.

The second aim of this project was to identify practical and cost-effective solutions based on farmers' demands. This is important because solutions based on industry input have the capacity to make real improvements to animal welfare in practice. This aim was addressed in the final two studies. In the fourth study, farmer's willingness to pay (WTP) for reductions in aggression was estimated through an economic choice experiment. Results revealed three independent sub-groups of pig farmer, each with different WTP and reasons for making the investment. Only one of these groups were motivated by animal welfare goals and were willing to pay to reduce aggression. By identifying the bounds of management change possible for farmers, it was ultimately possible to identify aggression control strategies which were compatible with these constraints. In the fifth study, the financial consequences of investing in three of the most practical and promising aggression control strategies were estimated. Results revealed that allowing litters to mix prior to weaning was a profitable aggression control strategy. Exposing pigs to synthetic maternal pheromones was unlikely to improve profitability. However, the costs were within the realms of the WTP for the

sub-group of farmers with animal welfare goals. Changing existing structures in order to house pigs in large social groups (100+ pigs) resulted in high economic costs which were beyond the realms of farmers' WTP.

Based on the findings of this project, several evidence-based recommendations were made to encourage a real change in practice. For example, animal scientists working on the control of aggression should test new strategies for their practicality and cost-effectiveness. Furthermore, communication within the industry must take place through targeted campaigns which take care to consider the wide variety of factors which influence farmers' behaviour. This project emphasises the importance of understanding human behaviour regarding animal welfare issues. Billions of agricultural animals are raised and slaughtered under human care, for human consumption, each year. This number is expected to continue rising with the growing human population. Therefore, the approach adopted in this project should be extended to other long-standing animal welfare issues.

Abstract

Aggression between pigs is common in commercial farming as pigs fight to establish dominance relationships at regrouping. The behaviour has been studied extensively since the 1970s and several strategies to reduce aggression have been identified. However, the uptake of aggression research in commercial practice has been limited and the behaviour remains an important problem for animal welfare, farm productivity and profitability. This thesis is the first body of work to study the social and economic factors influencing farmers' behaviour regarding the management of aggression, and adopted quantitative research methods in order to meet two primary aims. The first aim was to understand the behaviour of UK and Irish pig farmers with regard to aggression between pigs. This was important because understanding behaviour and the context in which it occurs can help to identify targets for initiating a change in practice. The second aim was to identify practical and cost effective solutions based on farmer demand. This is important because solutions based on industry input have the capacity to make real improvements to animal welfare in practice. At various stages of this project farmers' perceptions of pig aggression and welfare were compared to other stakeholder groups in order to establish the impact of farmers' role and experience. Comparison groups had experience of working with pigs but in a different context (specialised pig veterinarians); had

knowledge of agriculture and livestock but no experience of working with pigs (agriculture students and animal science students); and were removed from animal production (citizens unrelated to agriculture).

The first aim of this thesis was addressed in the first three studies. The results of the first study revealed widespread belief in pigs' capacity to suffer amongst pig farmers (and non-farmers). Therefore, a lack of belief in pigs' capacity to suffer does not appear to contribute to the non-financial reasons behind farmers' reluctance to control pig aggression. In the second study, participants' perceptions of aggression seen in video clips were compared to physiological measures of exhaustion (blood lactate) and injury (lesion score) taken from the animals. Results revealed that farmers' (and non-farmers) recognised fights displayed in-action as a source of suffering for pigs.

However, when they did not see the fight occurring but only saw the animals afterwards, participants underestimated pigs' injuries. In the third study, an in-depth analysis of the range of factors likely to influence farmer behaviour revealed that farmers' willingness to control aggression was influenced by: 1) whether they felt able to implement the change, 2) beliefs about the likely consequences, 3) perceptions of aggression as a problem on their farm, and 4)

the opinion of relevant stakeholder groups, with the opinion of veterinarians being particularly significant.

The second aim of this thesis was addressed in the final two studies. In the fourth study, an economic choice experiment revealed three independent groups of pig farmers, each with different willingness to pay (WTP) for aggression control strategies and motivation for making an investment. Specifically, farmers in Class 1 would not invest in an aggression control strategy as they were unlikely to regroup unfamiliar pigs. Farmers in Class 2 were willing to invest in an aggression control strategy, but were only interested in the extent to which the strategy improved growth rate. They were unwilling to pay for reductions in aggression specifically. Farmers in Class 3 were motivated by reducing aggression as well as improving growth rate, and were WTP £0.11 per pig place and £0.03 per pig produced for each 1% reduction in lesions as result of aggression. In the final study, cost-benefit analysis revealed that allowing litters to co-mingle prior to weaning is the most practical and economically viable aggression control strategy; meeting the demands of farmers in both Classes 2 and 3. Exposing pigs to synthetic maternal pheromones was unlikely to improve profitability, but did meet the WTP demands of farmers in Class 3. Changing current structures in order to

house pigs in large social groups (100+ pigs) was associated with high economic costs which were not within the realms of farmers' WTP. Overall, a major barrier preventing the uptake of aggression research in practice is that very few strategies can be practically and cost-effectively implemented and managed by farmers under commercial conditions.

Based on the findings of this project, several evidence-based recommendations were made to encourage a real change in practice. For example, animal scientists working on the control of aggression should test new strategies for their practicality and cost-effectiveness. Furthermore, communication within the industry must take place through targeted campaigns which take care to consider the wide variety of factors which influence farmers' behaviour. Applying the social sciences to stubborn and entrenched animal welfare issues has the capacity to bridge the gap between animal science research and practice, and have a huge impact on farm animal welfare. Therefore, the approach adopted in this project should be extended to other long-standing animal welfare issues where known solutions are poorly adopted.

List of abbreviations

AHDB	Agricultural and horticultural development board
AIC	Akaike Information Criterion
ANOVA	Analysis of variance
CAIC	Consistent Akaike Information Criterion
CBA	Cost benefit analysis
CL	Conditional logit
DCE	Discrete choice experiment
DEFRA	Department for Environment, Food and Rural Affairs
df	Degrees of freedom
EU	European Union
FAO	Food and Agriculture Organization
LCM	Latent class model
OECD	The Organisation for Economic Co-operation and Development
PLF	Precision livestock farming
QA	Quality assurance
REML	Residual maximum likelihood
RPL	Random Parameter Logit
RSPCA	The Royal Society for the Prevention of Cruelty to Animals
SLL	Simulated log-likelihood
SPSS	Statistical Package for the Social Sciences
SRUC	Scotland's Rural College
std	Standard deviation
TPB	Theory of planned behaviour
TRA	Theory of Reasoned Action
UK	United Kingdom
VAS	Visual analogue scale
WTP	Willingness to pay

Conference Proceedings

Peden, R.S.E., Camerlink, I., Boyle, L., Akaichi, F. & Turner, S.P. Farmer Perceptions of Pig Aggression Compared to Animal-Based Measures of Fight Outcome. **Oral presentation.** *International Society for Applied Ethology*, 8th August 2019, Bergen, Norway.

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Chapter 1: General introduction

1. Introduction

Aggression between pigs occurs regularly in intensive farming systems due to the unstable social structure created by regular regrouping. The behaviour has been extensively researched and various strategies to reduce aggression at regrouping have been identified. However, research efforts have had little impact on commercial practice, and aggression remains an important problem for both animal welfare and farm productivity. This chapter describes the problem of pig aggression in intensive farming systems, and ends with an overview of the following thesis chapters which address the issues highlighted.

2. Pig production

Demand for animal production for meat has grown rapidly over recent decades due to the growing population, growing incomes, and urbanisation (Boland et al., 2013). Although the growth in global demand for pigmeat is expected to slow down over the period 2018-2027, global production is still expected to rise by 11% (OECD/FAO, 2018). Since the late 1940's animal production has moved away from small, family run farms using extensive

farming systems towards larger, intensive systems. This has resulted in a decrease in the number of pig farms, and an increase in farm size (Cameron, 2000; Marchant-Forde, 2009a). These large, intensive units are sophisticated, highly engineered and designed to reduce manual labour, increase productivity and increase efficiency (Kittawornrat and Zimmerman, 2010). In Europe, these changes were supported by public policies that favoured more abundant and cheaper food (Lassen et al., 2006). Today, over 1.3 billion pigs are slaughtered worldwide each year and more than 50% are reared on intensive, commercial pig units (Compassion in World Farming, 2013; OECD/FAO, 2017)

There are essentially three different types of commercial pig unit (Marchant-Forde, 2009a). First, there are breeding units which only house the breeding herd and piglets up to weaning. Second, there are growing / finishing units which only house the pigs from weaning up to slaughter weight. The third type is a combined unit which houses both the breeding herd and the growing / finishing herd up to slaughter. In the EU, legislation requires that sows are group housed during gestation (Council Directive 2008/120/EC), and the majority of the sows housed in commercial production systems are moved into farrowing crates or pens about 7 days before they are expected to farrow. The crates, in contrast to 'free farrowing' pens (King et al., 2018),

restrict the sow's movement in order to reduce the risk of crushing their piglets (KilBride et al., 2012; Chidgey et al., 2015). Sows remain in crates until their litter is weaned at about four weeks old. In the UK, sows return to group housing following weaning, at this point they often meet unfamiliar sows and aggression occurs as they establish dominance relationships (Greenwood et al., 2014). Sows are usually serviced within one week following weaning and aggression can disrupt implantation (Arey and Edwards, 1998; Greenwood et al., 2014). In many EU countries, breeding sows can be kept in confinement for up to four weeks following service as the critical moment for implantation is at three weeks after conception (Council Directive 2008/120/EC). In some (but not all) countries outside of the EU, sows can be kept in stalls for the duration of gestation and are, therefore, in permanent confinement. Weaned pigs grown for slaughter are grouped with other litters at weaning, and are conventionally raised in groups of 15 – 50. Pigs typically move through multiple buildings or rooms as they grow from weaning to slaughter weight, requiring further changes to social groups (Marchant-Forde and Marchant-Forde, 2005; Camerlink and Turner, 2017). This occurs as farmers attempt to create groups of equal body size which market simultaneously, and because different buildings are designed for different group sizes (Camerlink and Turner, 2017; Ison et al., 2018). Once pigs reach slaughter weight, they may be regrouped again when loaded onto

lorries, and often again on arrival at the abattoir where they may be slaughtered quickly or held for up to 18 hours (Terlouw et al., 2008; D'Eath et al., 2010). It is well established that stress prior to slaughter leads to increased incidence of pale, soft, exudative (PSE) and dark, firm, dry (DFD) meat; thus, reducing meat quality (Adzitey & Huda, 2011).

3. Pig Aggression

Regular regrouping of unfamiliar pigs creates an unstable social structure and high levels of physical aggression caused by the animals' natural drive to establish a dominance hierarchy (McGlone, 1985). At each occurrence of regrouping, aggression is exhibited in well-defined behaviours, as aggressive pigs target the head, neck and shoulders of their opponent using bites and slashes from the canine teeth (Meese and Ewbank, 1973; McGlone, 1985). The function of aggression is ultimately to cause the withdrawal of a rival or opponent in order to achieve dominant status (Briffa and Sneddon, 2007). The establishment of a social hierarchy occurs within 24 hours of mixing, but the level of aggression drops dramatically after about 1 hour (Luescher et al., 1990). Once a period of social stability is reached, only an occasional threat or attack is necessary for an animal to reinforce its dominance (McGlone, 1986).

In order to understand this behaviour, it is necessary to understand the behaviour of the domestic pigs' ancestral species, the wild boar, with which they share this drive. Wild boar evolved to live in relatively small, stable social groups comprised of roughly 2 to 4 related sows, their most recent litters and juvenile offspring. Therefore, group members are related and display diverse bodyweights (Marchant-Forde, 2009b). As the litters mature, they may form subgroups of same sex individuals within the herd (or 'sounder'), or separate off to form a new sounder. Boars eventually become solitary as they mature into adults (D'Eath and Turner, 2009). Adult boars typically associate with the sounder only at mating, and when a boar joins a sounder they are dominant to all sounder members. Dominance is determined by maturity, size and strength, and subordinate animals tend to actively avoid conflict with dominant animals (Jensen and Woodgush, 1984). The complex, outdoor, home environment of the wild boar allows sounders to actively avoid confrontation with each other (Gabor et al., 1999). The home environment can be as large as 15,000 hectares annually, and population density can vary from 0.2 to 43 animals per km² (Massei and Genov, 2004). Furthermore, with the exception of males monopolising females during the mating season, there is little that dominant animals are able to monopolise. When aggression does occur, it is expressed in the same way as in the domestic pig (McGlone, 1985). However, the large home environment, stable

social groups, and clear variation in age and size generally allow wild boar to maintain dominance hierarchies with very little physical aggression. The high levels of physical aggression observed in commercial farming are a direct result of the unnatural social conditions whereby pigs are kept at high stocking densities, in unstable social groups, with pigs of a similar age and size, and where access to feed and dry lying areas can be monopolised.

Mixing aggression is associated with a number of negative outcomes which make it a substantial welfare and production issue in the pig industry. First, pigs suffer injuries mainly in the form of skin lesions (Turner et al., 2006), and also increased risk of lameness (Rydhmer et al., 2006). Second, pigs suffer from exhaustion and physical fatigue due to the substantial energy expenditure required, as indicated by increased blood lactate and glucose concentrations (Camerlink et al., 2016). These injuries and levels of exhaustion at slaughter can reduce meat quality parameters (D'Eath et al., 2010; Edwards et al., 2010a; Edwards et al., 2010b; Terlouw, 2005). Third, submissive pigs suffer restricted access to resources if these resources are limited. For example, sows with low social status may have restricted access to the feeder and drinker, and are denied access to the preferred lying areas more frequently, than high ranking sows (O'Connell et al., 2003). Finally,

stress as a result of aggression can threaten biological functioning. Stress is a biological response to an event that an individual detects as a threat to its homeostasis (Einarsson et al., 2008). It leads to activation of the hypothalamic-pituitary-adrenal axis and the sympathetic adreno-medullary system (Einarsson et al., 2008). Activation of these systems promotes the animals' ability to cope with immediate physical and/or psychological stressors by mobilizing glucocorticoid hormones (e.g. cortisol), and adrenaline and noradrenaline (Einarsson et al., 2008). However, ongoing activation of these systems can have negative, transient effects on the immune system (Morrow-Tesch et al., 1994), reproduction (Turner et al., 2002; 2005) and growth performance (Stookey and Gonyou, 1994; Coutellier et al., 2007).

Aggression has been studied extensively since the 1970s and as a result, a number of strategies to reduce the occurrence or intensity of aggression at regrouping have been identified. These strategies involve making specific changes to animal management, genetics and nutrition, and they have been reviewed several times (Petherick and Blackshaw, 1987; Marchant-Forde and Marchant-Forde, 2005; Greenwood et al., 2014). Specific strategies to reduce aggressive behaviour at regrouping include, amongst many others, allowing litters to mix prior to weaning, i.e. piglet socialization or co-mingling (D'Eath,

2005; Camerlink et al., 2018; Salazar et al., 2018), enhancing levels of tryptophan in the feed (Poletto et al., 2014) and employing direct selection against aggression by the use of skin lesions (Desire et al., 2015) or indirect genetic selection for growth, which is related to social interactions (Camerlink et al., 2012). An up-to-date review of the aggression literature is provided in Chapter 2.

4. Legislation and quality assurance standards governing aggression

In order to protect animal welfare, farmers in many countries are required to follow specific legislation. Council Directive 2008/120/EC specifies the minimum standards for the keeping of pigs in the EU. The legislation makes sparse requirements with regards to aggression, and the only strategy to control aggression that is specified (provision of plentiful straw) is not supported by any findings from research. Specifically, Council Directive 2008/120/EC states that regarding sows:

‘Measures shall be taken to minimise aggression in groups’

Whilst for weaners and growing pigs:

‘Measures must be taken to prevent fighting which goes beyond normal behaviour’

‘They should be kept in groups with as little mixing as possible. If pigs unfamiliar with one another have to be mixed, this should be done at as young an age as possible, preferably before or up to one week after weaning. When pigs are mixed they shall be provided with adequate opportunities to escape and hide from other pigs.’

‘When signs of severe fighting appear the causes shall be immediately investigated and appropriate measures taken, such as providing plentiful straw to the animals, if possible, or other materials for investigation. Animals at risk or particularly aggressive animals shall be kept separate from the group.’

‘The use of tranquilising medicaments in order to facilitate mixing shall be limited to exceptional conditions and only after consultations with a veterinarian.’

The majority of farmers are accredited with a quality assurance (QA) scheme membership and must, therefore, meet further standards (Hubbard et al., 2007b; Lever and Evans, 2017). In the UK, membership to basic schemes such as Assured British Pigs and Quality Meat Scotland are most common and driven by necessity in order to gain market access, as big retailers require their products come from quality assured farms (Bock and van Huik, 2007; Hubbard et al., 2007a; Compassion in World Farming, 2012). These schemes do not make any additional requirements regarding aggression beyond those required by legislation (Quality Meat Scotland, 2017; Red Tractor Assurance, 2019). Subgroups of farmers obtain membership to organic and welfare specific schemes, such as RSPCA Assured and the Soil Association. Although the animal welfare standards in these schemes are higher than minimum requirements, for example by restricting the use of farrowing crates and increasing space allowances, they do not make any specific requirements with regards to pig aggression (RSPCA, 2016; Soil Association, 2018).

5. Farmers' behaviour

For the reasons addressed above, pig aggression is a longstanding animal welfare and production issue in commercial farming which has been extensively researched. Legislation and QA standards do not provide specific recommendations on appropriate measures to take to reduce aggression between pigs. As a result, the implementation of aggression mitigation strategies identified by research strongly relies on farmers' willingness to participate in such initiatives. However, a survey of 167 UK pig farmers found that the majority do not perceive aggression as a problem that needs to be addressed (Camerlink and Turner, 2017). Research efforts to reduce aggression appear to have had little to no impact on commercial practice and projects on aggression continue to receive research funding as it is still considered an important animal welfare issue.

Human behaviour is determined by a wide variety of internal and external factors, and these factors can be targeted in order to change behaviour (Davis et al., 2015). It is, therefore, important to understand the determinants of farmers' behaviour regarding aggression in order to identify targets for implementing a change in practice. The literature on farmers' decisions regarding animal welfare more generally has revealed that economic factors

are the primary determinant of farmers' behaviour. Farm animals are business capital whose value is in direct proportion to their productivity and, although ensuring certain animal welfare standards can promote productivity, providing some improvements to animal welfare can be more expensive than the returns gained (Matheny and Leahy, 2007; Lusk and Norwood, 2011; Dawkins, 2017). Farmers are generally unwilling to take a negative effect on income (Gocsik, 2014), and whilst the main incentive to participate in an animal welfare scheme is improved profitability and market access (Bock and van Huik, 2007), the main barrier is distrust in the economic advantages of doing so (Bock and van Huik, 2007; Gocsik et al., 2015). As a result, the economic consequences of specific animal welfare improvements must be well established in order for farmers to implement them in practice. In addition to economic factors, farmers' decisions regarding animal welfare are also influenced by their personal perceptions, attitudes, knowledge, values, habits, traditions and social norms (Hemsworth et al., 1994; Willock et al., 1999; Coleman et al., 2000; Hemsworth, 2003; Alarcon et al., 2014). Yet, the financial consequences of aggression and strategies to control aggression have never been calculated, and little is currently known about how farmers make decisions regarding the management of aggression between pigs.

6. Research aims and objectives

The following thesis employs a multidisciplinary approach, using methods from animal science, social science and economics in order to meet the following two primary aims:

Aim 1: to understand the behaviour of UK and Irish pig farmers with regards to aggression between pigs.

Aim 2: to identify practical and cost-effective solutions based on farmer demand.

In order to meet these aims, the following seven research objectives were created:

Objective 1: to establish the current state of aggression research.

Objective 2: to establish the current practice of UK and Irish pig farmers with regards to aggression between pigs.

Objective 3: to establish farmers' perceptions of pig capacity to suffer.

Objective 4: to establish farmers' perceptions of aggression between pigs.

Objective 5: to identify the factors influencing farmers' willingness to implement aggression control strategies.

Objective 6: to calculate farmers' willingness to pay for a reduction in aggression.

Objective 7: to identify practical and cost effective solutions which meet farmer demand.

7. Thesis overview

This thesis consists of a general introduction (**Chapter 1**), a literature review (**Chapter 2**), five research chapters (**Chapters 3-7**) and a general discussion (**Chapter 8**).

Chapter 2 reviews the scientific literature in order to establish the current state of aggression research and identify the most promising research developments in controlling aggression at regrouping. Furthermore, the evidence of the uptake of this research in commercial practice is reviewed (**Objective 1 and 2**)

Chapter 3 investigates farmers' perceptions of pig capacity to suffer. Consumers reduce their perceptions of animal capacity to suffer in order to reduce the psychological discomfort associated with eating meat. I investigated for the first time if farmers employ a similar strategy to reduce psychological discomfort associated with meat production. This would have important implications for farmers' willingness to improve

animal welfare. Farmer perceptions of pigs' capacity to suffer were compared to perceptions of a livestock species that they do not farm (cows) and to non-livestock species (cats and dogs), as well as to those of agriculture students, animal science students, specialist pig veterinarians, and citizens unrelated to agriculture (**Objective 3**).

Chapter 4 explores farmers' perceptions of pig aggression, and investigates whether they may be desensitised due to frequent exposure to the issue. Farmers' perceptions of pig aggression seen in video clips are compared to animal based measures of exhaustion (blood lactate) and injury (skin lesions) obtained from the animals. Furthermore, farmers' perceptions are compared to those of people without experience of working with pigs (agriculture students and animal science students) and with comparable experience of working with pigs (specialist pig veterinarians) (**Objective 4**).

Chapter 5 establishes which aggression control strategies farmers have tried on their farm, and how useful they found each strategy to be. Whether or not farmers perceive aggression as a problem is established, and a structural equation model identifies the factors that influence farmers' willingness to reduce aggression in the future (**Objectives 2, 4 and 5**).

Chapter 6 utilises an economic choice experiment to estimate farmers' willingness to pay for a reduction in aggression, and establishes how farmers' trade-off different financial (production) and non-financial (welfare) factors when making investment decisions (**Objectives 6 and 7**).

Chapter 7 employs cost-benefit analysis to determine whether or not any existing aggression control strategies meet the demands of farmers' willingness to pay (**Objectives 6 and 7**).

Chapter 8 discusses the overall results in their wider context, including the implications for initiating a change in practice, directions for future research, reflection on the methodology used and ends with the final conclusions of the thesis.

This thesis takes the position that farmers, as animal caregivers, are ultimately responsible for making the necessary husbandry and management changes required to implement aggression control strategies in practice. Nevertheless, it is important to note that a change in animal welfare is piecemeal, and other stakeholder groups play important roles. Consumers and retailers have the capacity to influence animal welfare by creating a market pull towards animal friendly production. However, animal welfare

concerns generally do not influence consumer buying behaviour (Carrigan and Attalla., 2001; Harper and Henson, 2001; Harper and Makatouni., 2002; Te Velde et al., 2002; Schröder and McEachern, 2004; Belk et al., 2005; Auger and Devinney, 2007; Shaw Hughner et al., 2007; Carrington et al., 2010; Miele and Evans, 2010) and big retailers lack focus and attention on farm animal welfare (Lever and Evans, 2017). Veterinarians are responsible for ensuring animal health through prevention and treatment of animal injury and disease, and are the most trusted and influential source of animal welfare information to pig farmers (Alarcon et al., 2014). Therefore, specialist pig veterinarians are included in research in this thesis (**Chapters 3-4**), as well as citizens unrelated to agriculture (**Chapter 4**), and those likely to work with animals in the future (agricultural and animal science students, **Chapters 3-4**).

Chapter 2. Literature review

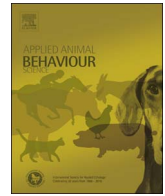
1. Introduction

In order to meet the two primary aims of this thesis (**Aim 1:** to understand the behaviour of UK and Irish pig farmers with regards to aggression between pigs; **Aim 2:** to identify practical and cost-effective solutions based on farmer demand), an important first step is to establish the current state of aggression research. This chapter consists of a published journal article which reviews the scientific literature on pig aggression in order to (1) identify all of the aggression control strategies proposed by research and (2) to identify the most promising developments in reducing aggression. This article also (3) reviews the industry literature for evidence of the uptake of this research in practice, and ends with (4) a discussion of why solutions may be insufficiently adopted by farmers and a number of potential resolutions. Following the published journal article, I insert an overview of research published on aggression after the literature review was published in March 2018. Finally, the chapter ends with concluding remarks leading into the following five research chapters.

2. Journal article

Declaration

Rachel Peden conducted the following review of the academic literature and produced the first full draft of the manuscript. Irene Camerlink, Simon Turner and Laura Boyle all provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to external peer review comments and prepared the response letter for the journal and was the corresponding author. Inclusion of this publication complies with copyright laws. Permission from co-authors was obtained regarding the inclusion of this article in the current thesis.



The translation of animal welfare research into practice: The case of mixing aggression between pigs

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ABSTRACT

Aggression between unfamiliar pigs at mixing is a major animal welfare problem in commercial farming. It has been studied since the 1970s and remains an important topic in animal welfare research. Methods to reduce pig aggression at mixing have been reviewed previously, but there has been little translation of the advocated techniques and building designs into practice. As a result, the problem persists on many commercial units. A similar situation exists for many other animal welfare issues. This article takes a new approach in not only reviewing the recent scientific literature, but also reviewing the evidence of uptake in industry. Firstly, the current state of aggression mitigation research is reviewed; including the most successful recent developments in breeding against aggression, early life socialisation, the use of pheromones and nutrition. Secondly, information is extracted from both peer reviewed and industry literature to establish the extent to which these strategies have been transferred from research to practice. Finally, we discuss why in spite of the amount of research on reducing aggression at mixing the problem has not reduced in intensive farming systems. The limited uptake in practice appears to be due to low prioritisation of the problem, the practicalities of implementation, lack of information on cost-effectiveness and ineffective communication of research to the farming community. To bridge this gap, industry must be involved in the design of practical solutions and the cost-effectiveness of these must be quantified. This approach should also be considered for other animal welfare issues under investigation. We recommend a better alignment between research questions and industry interests to increase the success of research efforts to improve animal welfare in practice.

1. Introduction

When regrouping ('mixing') unfamiliar pigs, aggression occurs as they establish a dominance hierarchy. 'Mixing aggression' between both growing pigs and sows is a major animal welfare issue. It has been studied since the 1970s and a large body of peer-reviewed literature exists. Many strategies to reduce aggression have been identified. Methods for growing pigs and sows were reviewed by Marchant-Forde and Marchant-Forde (2005), whilst other reviews focussed specifically on growing pigs (Petherick and Blackshaw, 1987) or sows (Arey and Edwards, 1998; Greenwood et al., 2014). Despite the amount of past and on-going research, aggression at mixing is largely undiminished in practice, which is partly evidenced by the on-going research efforts on this topic. Projects on aggression in pigs continue to receive funding as it is still regarded an important welfare issue. In fact, research on pig aggression has increased since the reviews cited above (Fig. 1). Data

from 1,928 farms in the UK show a prevalence of 0.24% for severe skin lesions (Pandolfi et al., 2017) and 11% for mild body lesions (Real Welfare, 2017), which are a result of aggression.

Aggression between pigs arises from their need to establish and reinforce dominance relationships (McGlone, 1985). Although aggression is a natural behaviour, it is exacerbated by unnatural intensive farming conditions and practices such as social disruption, limited space and homogeneity in competitive ability of group members. In the wild, pigs live in small stable groups where subordinate animals tend to actively avoid conflict with dominant animals (Jensen and Wood-Gush, 1984), and males actively avoid confrontation with each other outside of the mating season (Gabor et al., 1999). Social hierarchies are therefore maintained mostly through agonistic display and with little physical aggression. In commercial pig production pigs are regrouped several times from birth to slaughter (Camerlink and Turner, 2017). Regrouping is a common management strategy 1) to create groups

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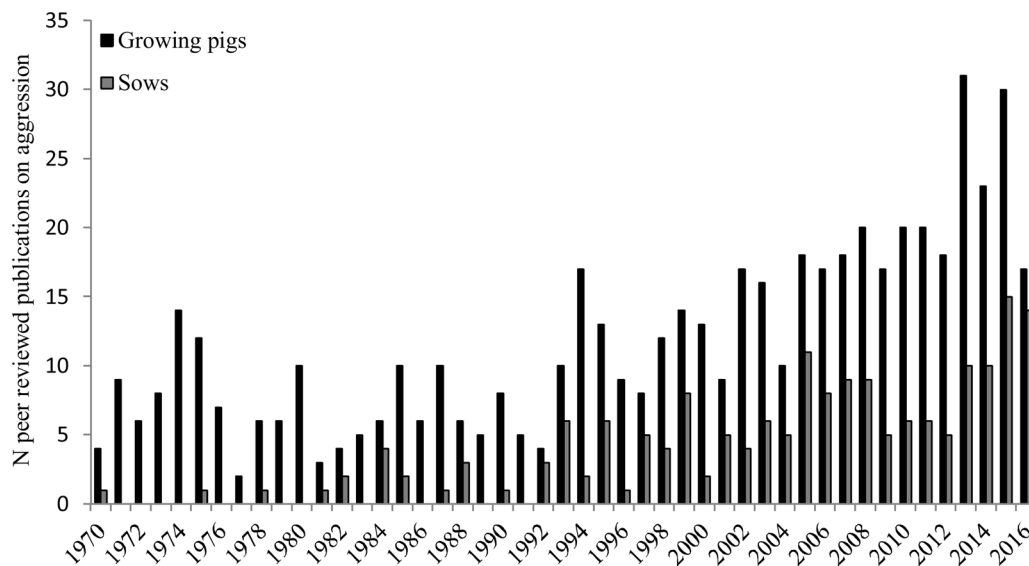


Fig. 1. The number of published peer reviewed articles written on aggression in growing pigs and sows since 1970. Information obtained by running two separate Scopus searches and noting the number of hits per year (searched 'aggression AND pigs' and 'aggression AND sows').

appropriate to the size of the pens available (Guy et al., 2009); 2) to equalise body weights to achieve more homogenous slaughter weights (Rushen, 1987); and 3) to return breeding sows to the gestation group after weaning. Farmers report mixing growing pigs up to four times during production (Camerlink and Turner, 2017). For the majority of farmers, the avoidance of mixing is impractical due to inefficient use of space and concern that heterogeneity in pig weights will be exacerbated. Moreover, the mixing of sows is unavoidable in the EU due to EU Council Directive 2008/120/EC which requires that sows and gilts are group housed from 4 weeks after service to 1 week before expected farrowing. Regrouping, and thus aggression, is therefore common at weaning (for both piglets and sows), at the beginning of the growing-finishing period (Manteca and Jones, 2013) and at transport to slaughter (Terlouw et al., 2008).

Aggression has a negative impact on farm profit and animal welfare. During fights pigs acquire skin injuries as a result of bites (McGlone, 1985), risk lameness (Rydhmer et al., 2006), and are more susceptible to infection due to the transient effects of stress upon the immune system (Morrow-Tesch et al., 1994). Aggression can negatively affect growth rate (Stookey and Gonyou, 1994; Coutellier et al., 2007) and meat quality (D'Eath et al., 2010). In sows, aggression can result in economic losses due to reduced reproductive performance (Mendl et al., 1992; Greenwood et al., 2014). The movement away from individual sow stalls, which is now taking place globally, means research into aggression when re-grouping sows is of increasing importance (e.g. Greenwood et al., 2014; Ison et al., in press).

In this paper we review the current state of research into reducing mixing aggression between growing pigs and sows, and identify the most promising techniques in terms of their scientific progress. Moreover, we review the impact of these strategies on commercial practice, and address why the large amount of research on this topic has failed to reduce aggression on commercial pig farms. Finally, we provide suggestions on how to bridge the gap between animal welfare research and actual animal welfare improvement. We focus specifically on the aggression that occurs between unfamiliar pigs at regrouping. Strategies to address problems of aggression between pigs in stable groups are not explored in this review.

2. Method of selecting literature

The review of aggression mitigation strategies for both sows and growing pigs carried out by Marchant-Forde and Marchant-Forde

(2005) was used in this review to refer to the scientific literature up to 2005. Peer-reviewed literature published between 2005 and 2017 was identified using Google Scholar and Web of Science using the following search terms: Pig, Sow and Aggression. The uptake of methods to reduce aggression in practice was assessed through data from farmer surveys and a Web based search of commercial publications, websites, and farmers' magazines. Findings from farmer surveys were identified using Google Scholar and Web of Science under the following search terms: Pig, Sow, Aggression and Survey. Websites included those of pig farming magazines, pig breeding companies, pig feed companies and equipment manufacturers or suppliers based in the United Kingdom. Information obtained from websites included items promoting specific aggression mitigation strategies and the availability of relevant products on the market. Social media, blogs, and posts by lay people were excluded. Literature on aggression between pigs in stable groups was also excluded.

3. Current state of research

In this section we summarise the successful methods to reduce aggression identified in previous reviews. Thereafter, four newer approaches are described, namely: genetic selection, nutritional supplementation, early-life socialisation and use of pheromones. In recent years these four approaches have emerged as some of the most promising aggression mitigation strategies in terms of their scientific progress and practical impact.

3.1. Previously identified control strategies

Research has moved away from methods that do not deliver long term benefits and prove difficult to manage under commercial conditions, such as tranquilisers, boar presence and variation in weight at mixing (described by Marchant-Forde and Marchant-Forde, 2005). Methods with continued efficacy in empirical studies include providing adequate space (Spooler et al., 2009; Hemsworth et al., 2013) and large social groups (Samarakone and Gonyou, 2009). Space allowance should be sufficient for pigs to display submissive behaviour (Turner et al., 2000; Spooler et al., 2009; Hemsworth et al., 2013); however, to date it is difficult to define what can be regarded as adequate space allowances for growing pigs and sows, partly since this is affected by floor type and feeding system design. Group size must be sufficiently large (more than 12 individuals) to have an impact on aggression levels

(Andersen et al., 2004), however much larger groups (> 80 pigs) are more effective (Turner et al., 2001; Samarakone and Gonyou, 2009). It is suggested that the reduction in aggression with increasing group size is related to the formation of subgroups of a more natural size when pigs can no longer maintain a definitive social order (Gonyou, 2001). However, there is no clear evidence for this in domestic pigs (Turner et al., 2003), and it more likely reflects the adoption of a less aggressive social strategy when the costs associated with aggression outweigh the benefits (Andersen et al., 2004; Samarakone and Gonyou, 2009).

3.2. Advances in genetics

Aggressiveness is a moderately stable temperament trait with consistent differences existing between individuals. For example, resident pigs exposed to intruders at three time points (60, 95 and 130 days old) revealed consistency in their aggressive behaviour within and between interactions (Clark and D'Eath, 2013). The distribution of aggressive behaviour within a group tends to be skewed by the presence of a minority of highly aggressive animals (Turner et al., 2006b). The aim of breeding against aggression would be to reduce the aggressiveness of all animals in the population with greatest impact on the occurrence of highly aggressive individuals. Reciprocated fighting and the delivery of non-reciprocated bullying have a moderate heritability ($h^2 = 0.17\text{--}0.43$) (Lovendahl et al., 2005; Turner et al., 2008, 2009) whereby the heritability indicates the proportion of the phenotypic variance that can be attributed to additive genetic effects. Reciprocated fighting involves decisions made by two pigs and the significant heritability estimated for this behaviour reflects an individual's propensity either to initiate aggression or to retaliate aggressively when attacked, leading to a reciprocal fight. However, the heritability for the receipt of bullying is low ($h^2 = 0.04\text{--}0.08$; Lovendahl et al., 2005; Turner et al., 2009). Skin lesions are used as a proxy measure of aggression, with a differentiation being made between skin lesions due to reciprocal fighting (primarily located on the head, neck and shoulders) and lesions due to the receipt of bullying (primarily located on the flanks, back and rump) (Turner et al., 2006a; Desire et al., 2015b). Skin lesions, particularly towards the front of the body, are genetically correlated with engagement in reciprocal fighting and pigs which perform this behaviour typically also direct non-reciprocated bullying towards others (Turner et al., 2009). Therefore the amount of lesions and their location on individual pigs can be used as a genetic indicator trait to select against the expression of reciprocal fighting and aggressive behaviour (Turner et al., 2006b, 2008, 2010; D'Eath et al., 2010; Desire et al., 2015a,b).

Counting lesions takes less than 2 min per animal (Turner et al., 2009) and requires no additional animal handling, no equipment and minimal training (Turner et al., 2010). Therefore genetic selection on the basis of skin lesions has the potential to lead to cumulative and long term benefits at relatively little cost to individual producers. However, the costs of recording lesions (phenotyping) and the reduction in selection pressure that can be exerted on other traits in an index by the inclusion of a new trait are barriers to selection against skin lesions. Furthermore, there is evidence from one population that reducing skin lesions may slow genetic progress in growth rate and feed efficiency (Desire et al., 2015a) due to an undesirable genetic association between the traits. Nevertheless, it is important to note that lesions are primarily received to the anterior part of the body during aggressive behaviour and these are not genetically related to production traits (Desire et al., 2015a).

A novel approach to address animal welfare issues through breeding is through indirect genetic effects (IGEs, also known as social or associative genetic effects). An individual's performance is influenced not only by its own genotype, but also by that of the individuals with which it interacts (Moore et al., 1997; Ellen et al., 2014). IGEs refer to the genetic effects that an individual has on the phenotype of its group mates. These effects can have either positive or negative implications

for welfare, productivity, and health of livestock and are hypothesised to be related to behaviour (reviewed in Ellen et al., 2014). Indeed, research on the behaviour of pigs selected for positive IGEs regarding productivity showed differences in biting behaviour (Canario et al., 2012; Camerlink et al., 2013). IGEs may, therefore, provide a promising method for reducing negative social interactions whilst improving productivity. This approach negates the need for additional phenotyping as it is expected to change social behaviour as an indirect consequence of improving productivity traits that are already recorded.

3.3. Nutrition

Scientific research on how nutrition can reduce aggression is sparse but promising. There is some evidence to suggest that magnesium supplementation may reduce aggressive behaviour at mixing (O'Driscoll et al., 2013a, b), although there is also evidence to suggest that it can actually increase the frequency of aggressive behaviour (Caine et al., 2000). Therefore further research is required to establish the effect of magnesium on aggression and the optimum supplementation level.

Dietary manipulation of amino acid precursors of neurotransmitters may offer a practical means of reducing susceptibility of pigs to stress (Adeola and Ball, 1992; Koopmans et al., 2005). Tryptophan (TRP) is an essential amino acid acquired through the diet, and is typically supplied at levels required for maximum growth (Li et al., 2006). The supply of excess TRP may be used as a therapeutic supplement as it is the primary precursor for serotonin (5-HT), an inhibitory neurotransmitter in the central nervous system (Li et al., 2006). Serotonin regulates a variety of processes such as sleep, appetite, mood, susceptibility to stress and aggressive behaviour (D'Eath et al., 2005; Koopmans et al., 2005; Poletto et al., 2010). By feeding pigs a high TRP diet it is possible to indirectly raise brain availability of 5-HT (Adeola and Ball, 1992; Koopmans et al., 2006; Shen et al., 2012a). A four day enhanced TRP diet was associated with a 50% decrease in fight duration and intensity at regrouping in male and female growing/finishing pigs compared to an untreated control group (Li et al., 2006). There was no effect of an enhanced TRP diet on the number of fights that occurred or the latency to fight (Li et al., 2006). Poletto et al. (2010) found that a high TRP diet significantly reduced the aggressiveness of grower gilts in a resident intruder test as they took longer to attack the intruder pig and they initiated fewer fights (Poletto et al., 2010). Moreover, providing a TRP-enriched diet around mixing led to a reduction in aggressive behaviour in gestating sows (Poletto et al., 2014), although Li and co-authors (2011) did not find such an effect (Li et al., 2011). Hypothalamic 5-HT concentrations peak after 4–5 days of eating an enhanced TRP diet (Adeola and Ball, 1992; Koopmans et al., 2005), and this was missed in the study of Li et al. (2011).

A TRP-enriched diet is also associated with reduced salivary cortisol (Koopmans et al., 2005; Guzik et al., 2006; Koopmans et al., 2006; Shen et al., 2012a) and reduced adrenaline and noradrenaline at regrouping (Koopmans et al., 2005). Moreover, growing pigs with a TRP-enriched diet display a reduced long term hormonal response to regrouping, indicating enhanced recovery following social confrontations (Koopmans et al., 2005). When weaned pigs are placed on a TRP-enriched diet immediately following weaning, no adverse effects on feed intake and average daily gain are reported (Koopmans et al., 2006) and there can be improvements in feed efficiency (Shen et al., 2012b). However, there is no reduction in aggressive behaviour when mixed five days after weaning (Koopmans et al., 2006).

3.4. Early life socialisation

Early life socialisation of piglets, also termed co-mingling, involves the mixing of litters during the lactation period and is probably the most studied method for mitigating aggression at weaning. Suckling litters are allowed to integrate usually in the second week of life, when piglets would start to encounter other litters under natural conditions

(Stolba and Wood-Gush, 1989), and remain together until weaning. Unless using purpose-built multi-suckling systems, in which piglets naturally co-mingle, socialisation requires the removal of the barriers between adjacent farrowing pens (Hessel et al., 2006).

There is little increase in agonistic behaviour in piglets at pre-weaning socialisation (Weary et al., 1999), and when aggression does occur it is without the risk of severe injuries due to the limited size and strength of young piglets (Ledergerber et al., 2015). This social experience results in reduced aggression at weaning, and is presumed to do so by allowing piglets to learn social skills which permit more rapid formation of stable dominance relationships in subsequent social encounters (D'Eath, 2005; Kanaan et al., 2008; Kutzer et al., 2009). Moreover, pre-weaning socialisation can improve weaner performance by increasing growth rate following weaning (Hessel et al., 2006; Ledergerber et al., 2015).

There is some concern that the benefits of socialisation may be offset by production costs resulting from a disruption to pre-weaning feeding behaviour (Wattanakul et al., 1997b; Parratt et al., 2006). The main concern regards cross-suckling, which can lead to reduced milk intake due to competitive exclusion of subordinate piglets (Pedersen et al., 1998) and a disruption to sow lactation at mixing (D'Eath, 2005). There is inconsistent evidence regarding the prevalence of cross-suckling in multi-suckling systems; some studies found that it occurred frequently (Wattanakul et al., 1997a; Olsen et al., 1998; Maletinska and Špinka, 2001) whilst others did not (D'Eath, 2005; Kutzer et al., 2009). Moreover, there is evidence to suggest that even where cross-suckling is common it does not have an adverse effect on the overall milk intake of the piglets (Maletinska and Špinka, 2001). Experimental studies suggest that pre-weaning socialisation of pairs of litters does not affect pre-weaning growth rate (D'Eath, 2005; Kanaan et al., 2008) or mortality (D'Eath, 2005). However, heightened mortality was observed in multi-suckling systems where more than two litters were simultaneously co-mingled (van Nieuwamerongen et al., 2015).

3.5. Pheromones

Pig appeasing pheromone (PAP) is a maternal pheromone released by sows through skin secretions, and functions to regulate nursing behaviours (Morrow-Tesch and McGlone, 1990). Pageat (Pageat, 2001) synthesised a mixture containing several fatty acids similar in composition to PAP and it is currently on the market as an odour diffuser to reduce pig aggression. This synthetic pheromone reduces the frequency of fights at mixing in sows (Yonezawa et al., 2009; Plush et al., 2016) and weaners under experimental (McGlone and Anderson, 2002) and commercial farming conditions (Guy et al., 2009). This technique is therefore targeted at breeding and weaner stock. Research applying synthetic PAP in either aerosol or liquid form directly to pens and feeders found that pigs showed a reduction in salivary cortisol (Yonezawa et al., 2009) and skin lesions related to aggression (Guy et al., 2009) and a higher average daily weight gain (McGlone and Anderson, 2002) when compared to pigs not exposed to PAP. The use of synthetic PAP for sows does not appear to affect the subsequent conception rate (Plush et al., 2016). The number of skin lesions in groups exposed to synthetic PAP is reduced up to seven days following mixing (Guy et al., 2009), suggesting that it does not merely postpone the occurrence of aggression but results in the more rapid formation of stable social relationships (Guy et al., 2009).

4. Implementation of aggression mitigation methods in practice

We summarise the translation of aggression research into commercial practice in Table 1. All aggression mitigation methods were tabulated, even those that research found ineffective but industry found useful in the study of Ison et al. (in press). Methods were grouped by breeding strategy, nutrition, and management adaptations. In the rest of this section, we summarise the evidence for implementation of the

most promising control strategies. Firstly, we summarise uptake of the most promising previously identified strategies (increased space allowance and group size) before summarising uptake of the most promising recent developments in aggression research (genetic selection, nutritional supplementation, early life socialisation and use of appeasing pheromones).

4.1. Previously identified control strategies

A recent survey found that only two respondents from a sample of 132 British and Irish pig farmers reported using increased space allowance to control aggression at mixing (Peden et al., Unpublished work) suggesting limited uptake of this strategy in practice. Keeping pigs in large groups of anything from 50 to 1000 pigs gained popularity over the last 15 years (Gadd, 2009) due to a reduction in aggressive behaviour (Turner et al., 2001; Samarakone and Gonyou, 2009), and benefits in terms of reduced cost and ease of management (Gadd, 2009). The growth in group size for growing pigs has been accelerated by the development and launch of Automatic Sorting Technology (AST) in 2002, which is based on maintaining pigs in groups of 500–1000 (Brunner et al., 2008).

4.2. Breeding

Although direct genetic selection against aggression shows promise and continues to be researched it is not being implemented in pig breeding schemes. The finding that lesions to the anterior part of the body (which are most associated with aggressive behaviour) are not genetically related to production traits (Desire et al., 2015a) is promising for future implementation. As the costs of high density genotyping (i.e. determination of the nucleotide identity at many locations on the genome) fall, genomic selection based on lesions is likely to become more feasible and will avoid the need for routine phenotyping. The estimation of indirect genetic effects, which could also affect aggression, is routinely conducted by two large pig breeding companies and is being evaluated by others. To date, only a limited number of lines selected for indirect genetic effects are commercially available from two companies.

4.3. Nutrition

Several articles have appeared in popular farmer magazines and websites that promote the use of an enhanced tryptophan diet to reduce aggression (Dapoza, 2009; Ziggers, 2009; National Hog Farmer, 2010; Phys.Org, 2010; Salvage, 2010; ter Beek, 2010; Ziggers, 2010). Despite these, tryptophan is not commonly used above the minimum requirements for growth in commercial practice. Tryptophan is not readily available for supplementing feed, nor is its supplementation routinely recommended by feed companies. This is likely related to the inconsistent dose response reported in the literature, and lack of information on the economic benefits. In order to bring enhanced TRP out of the research phase and into practical application we recommend that research establishes the optimum dose and the associated cost to farmers. Moreover, it is important to establish a way of administering an enhanced TRP diet for the necessary period with minimal disruption to management.

4.4. Early life socialisation

A recent survey amongst UK pig farmers indicated that 27% of the 167 respondents currently applied socialisation of piglets, or had done so in the past (Camerlink and Turner, 2017). However, 50% of participants said they would not employ socialisation, and most raised multiple concerns about the strategy. The most frequently mentioned concern regarded the practical management of piglets and sows (60%), followed by aggression of the sow towards piglets (37%) and reduced

Table 1
Summary of aggression mitigation strategies.

Strategy	Benefits	Barriers to implementation	Recently researched	Implementation in practice	Literature
Breeding					
Genetic selection	Reduced aggressiveness of population, relatively little cost to individual producers	Cost of phenotyping, reduced selection pressure on existing index traits	Yes	Limited	(Lovendahl et al., 2005; Turner et al., 2006a,b; Turner et al., 2008; Turner et al., 2009; Desire et al., 2015a,b)
Breeding for indirect genetic effects	Reduced aggressiveness of population as an indirect result of selecting for existing production traits, no need for additional phenotyping	Difficulties in the modelling, estimation and interpretation of indirect genetic effects	Yes	Limited	(Camerlink et al., 2012; Canario et al., 2012; Bijma, 2014)
Nutrition					
Tryptophan rich diet	Reduced aggression and stress	Extra feed costs, lack of established protocol regarding optimum dose and duration	Yes	Limited	(Koopmans et al., 2005; Guzik et al., 2006; Koopmans et al., 2006; Li et al., 2006; Poletto et al., 2010; Shen et al., 2012a,b; Poletto et al., 2014)
Magnesium rich diet	Some evidence of reduced aggression	Inconsistent evidence of efficacy, extra feed costs, lack of established protocol regarding optimum dose and duration	Yes	No	(Caine et al., 2000; O'Driscoll et al., 2013a, 2013b)
Management					
Early life socialisation	Reduced aggression at weaning	Extra work load, farmer concerns over pathogen spread, growth and mortality	Yes	Yes	(Weary et al., 1999; D'Eath, 2005; Hessel et al., 2006; Kanaan et al., 2008; Kutzer et al., 2009; Ledergerber et al., 2015)
Pheromones	Reduced aggression in breeding and weaner stock	Costs, little scientific evidence of effectiveness of commercially available diffusers, requirement for optimal application protocol	Yes	Limited	(Paget, 2001; McGlone and Anderson, 2002; Guy et al., 2009; Yonezawa et al., 2009; Plush et al., 2016)
Large social group sizes	Reduced aggression, lower fixed costs per pig	Heterogeneity in weight gain, difficulty in handling, inappropriate dunging patterns	Yes	Yes	(Turner et al., 2001; Andersen et al., 2004; Samarakone and Gonyou, 2009)
Mixed weight groups	Reduced aggression	Reduced efficiency of space use, restricted access to resources for low weight pigs, increased divergence in weight as pigs grow	No	No	(Rushen, 1987; Francis et al., 1996; Jensen and Yngvesson, 1998; Andersen et al., 2000)
Avoidance of mixing (farrow-to-finish systems)	Prevents regrouping aggression entirely, minimises pathogen spread	Not practical for most existing farms due to inefficient space use, farmers believe that avoidance of mixing will exacerbate heterogeneity in pig weights, Council Directive 2008/120/EC requires sow and gilt group housing during gestation	No	Limited	(Fredriksen et al., 2008)
Increased space allowance	Easier signalling of submission reduces mixing fight duration	Reduction in efficiency of building space use	No	Limited	(Turner et al., 2000; Spoolder et al., 2009; Hensworth et al., 2013)
Interruption with cognitive enrichment	Pigs are trained to respond to a noise stimulus, this can be used to interrupt aggressive encounters	High labour requirements make it impractical for most commercial farms	Yes	No	(Rautenberg et al., 2013; Sonoda et al., 2013; Ismayilova et al., 2014)
Solid visual barriers, escape areas or pop-holes to hide head and neck	Allows subordinates to avoid aggression	Inconsistent evidence of efficacy, costs of installation, greater labour costs for inspection and cleaning	Yes	Limited	(McGlone and Curtis, 1985; Edwards et al., 1993; Olesen et al., 1996; Bultens et al., 2017)
Tranquilliser (azaperone)	Initial reduction in mixing aggression	Aggression is only delayed rather than reduced	No	Yes	(Blackshaw, 1981; Gonyou et al., 1988; Tan and Shackleton, 1990)
Boar presence	Possible minor reduction in sow aggression	No clear effect, increased sow stress, impractical on farm	No	No	(Grandin and Brunning, 1992; Seguin et al., 2006)
Mixing at night	Initial reduction in mixing aggression, little disruption, investment or cost to farmers	No clear effects, postpones aggression until morning	No	Limited	(Barnett et al., 1994)

* To the best of our knowledge based upon peer reviewed and industry literature.

growth of piglets (32%). These concerns are not supported by experimental trials but results in practice may differ from those generated under highly controlled experimental conditions. Producers may be more willing to implement early-life socialisation if more evidence is provided and disseminated to demonstrate that growth and mortality are comparable to standard practice (Ison et al., *in press*).

Implementation of this technique outside of the UK is currently unknown. Unusually, as much as 40% of the British pig herd is outdoor bred (Agriculture and Horticulture Development Board, 2016), and early life socialisation frequently occurs as a consequence of these outdoor rearing systems. Therefore implementation reported in the UK is likely to be relatively high in comparison to countries where indoor intensive breeding systems are more common. Indeed, a recent survey of North American producers found poor uptake of socialisation in these systems (Ison et al., *in press*). It is worth noting that those who used the technique found it to be more useful than any other mitigation strategy (Ison et al., *in press*).

4.5. Pheromones

PAP diffusers have been commercially available from at least one company since 2015 (Semikeys, 2018a); they advise that one diffuser covers an area of 25 m² and should be replaced every six weeks. Importantly, the Semikeys website provides a calculator allowing customers to track behavioural changes in their treated pens, compare performance to untreated controls, and to assess the economic impact of using pheromones on their own farms (Semikeys, 2018b). Furthermore, several articles were written in French magazines and newsletters promoting the product. These mainly report the positive effects of the product, including: reductions in the number of fights, the duration of fights, cortisol, lesions, and tail biting (Huet, 2016; Semikeys, 2016, 2017).

The majority of published research into PAP applied the pheromone in either liquid or aerosol form directly to the pens and feeders, and did not employ the commercially available diffusers. The only published research investigating the effectiveness of diffusers found limited efficacy (Plush et al., 2016). Research into PAP is ongoing and it is recommended that priority is given to determining the optimal application protocol under commercial conditions.

5. The gap between research and practice

Farmer willingness to change current practice and implement strategies to reduce aggression relies strongly on their perception of the situation. Pig farmers self-report having high regard for animal welfare (Wilson et al., 2014). However, they are faced with a myriad of often competing welfare problems such as tail biting; lameness; pain caused by routine husbandry procedures such as ear tagging and tail docking (Wilson et al., 2014); and heat stress (Pearce et al., 2013). Welfare may also compete with profit margins, food safety, product quality and environmental regulations (Millman et al., 2004). Therefore several factors compete for farmer attention, and it is possible that the costs associated with aggression are perceived as minor in comparison to those incurred by other threats to welfare and production. In a recent survey in the UK, 73% of 167 farmers did not regard aggression at weaning as a problem that needed to be addressed, compared to 57% at the growing-finishing stage (Camerlink and Turner, 2017). The farmers who perceived aggression as a problem displayed variable willingness to change the situation (Camerlink and Turner, 2017). This variation in response probably reflects the fact that human behaviour is determined by a wide range of intrinsic and extrinsic factors such as culture, social norms, education, awareness of legislation, attitudes, age and gender. Such factors were influential in determining antibiotic use, and campaigns that understood and addressed them managed to change human behaviour in both medical and agricultural/veterinary practice (Sabuncu et al., 2009; Huttner et al., 2010; Aarestrup, 2012).

Characteristics of the aggression mitigation strategy are also important. Reluctance to implement welfare improvement strategies is associated with the perception that they are ineffective, not financially feasible, or difficult to practically manage (Fredriksen and Nafstad, 2006). Motivation is limited when farmers distrust the economic advantages of implementing strategies or when the benefits are simply unknown (Bock and van Huik, 2007; Gocsik et al., 2015). Motivation is also reduced by a perceived lack of time, skilled labour (Morgan-Davies et al., 2006), or knowledge (de Lauwere et al., 2012). Commercial pig farmers have little choice but to farm animals in a way that will retain their competitive position in the market (Webster, 1982), and pig farmers are motivated markedly by economic factors (Bock and van Huik, 2007). Farmers are willing to adopt higher animal welfare standards as long as they fit the current farm set-up, are reversible and cover the additional costs (Gocsik et al., 2015). The lack of insight into the economic costs of aggression is likely to limit farmers' willingness to put resources into controlling the problem. There is a need for cost-effectiveness analysis of aggression mitigation strategies to identify the most economically feasible approaches. This should complement efforts to quantify farmers' willingness to pay for welfare improvements that take the different capital and labour costs of implementing strategies into account.

Effective communication between researchers and farmers is vital at all stages of the research process for the successful development, acceptance, and adoption of innovations or techniques (Clarke, 2003). It is acknowledged that, although communication of science is important, it is generally not done well (Treise and Weigold, 2002) and requires improvement (Clarke, 2003; Grandin, 2003). It was previously recognised that there is a need for one-to-one communication and discussion, and for a move away from the unidirectional lecture format that both intimidates farmers and denies scientists the opportunity to respond based on the knowledge base of their audience (Clarke, 2003; Benard and Buning, 2013). For innovations to be implemented into industry they need to be well communicated and tested, and early adopters need to be supported to ensure successful implementation (Grandin, 2003). Who delivers the information may be important. Alarcon et al. (2014) found that veterinarians are a trusted source of information whilst researchers are associated with several negative themes, such as 'lack of communication', 'not knowing where to look', and 'information bias' (Alarcon et al., 2014). Therefore, the support of mitigation strategies by veterinarians may improve the practical application of research findings.

Societal concern about animal welfare has driven change in practice for several animal welfare issues, with campaigns to bring change either resulting in government regulations or change in retailer standards, for example in restricting use of conventional battery cages for laying hens (Appleby, 2003), sow stalls and veal crates for calves in the EU (Druce and Lymbery, 2006). A European Commission study found that 76% of EU citizens (from a sample of over 24,000) believe that they can influence the welfare of farmed animals for the better through their purchasing behaviour (European Commission, 2005). However, consumers have limited knowledge of intensive animal husbandry systems (Schröder and McEachern, 2004), and problems like pig aggression are unknown to the majority of society and therefore may not drive industry towards change on this matter.

6. Conclusions and recommendations

Mixing aggression between pigs continues to be an important topic in animal welfare research as the problem persists in practice. Although research has identified a number of aggression mitigation strategies they are not being implemented much at industry level. Apart from keeping pigs in stable groups throughout the production cycle there is no unified solution to effectively reduce aggression. Rather, aggression like many other welfare problems requires a multidisciplinary solution. Breeding and pre-weaning socialisation can help animals to better cope

with the commercial farming environment. Housing pigs in relatively large groups, while providing a diet high in tryptophan, and providing synthetic maternal pheromones and sufficient space, may create an environment that reduces aggressive behaviour. There is minimal uptake of these mitigation strategies which may be due to low prioritisation of the problem, the practicalities of implementation, ineffective communication of research to the farming community and economic factors.

We recommend that researchers provide evidence that strategies are practical in a commercial farming environment; that they calculate the economic cost-effectiveness of doing so; and that they effectively communicate this information to farmers and other stakeholders. Where possible, farmers and other stakeholders should be involved in the early stages of a project so that they can contribute effectively to designing interventions. We recommend a better alignment between research questions and industry interests to increase the success of research efforts to improve animal welfare in practice.

Conflicts of interest

The authors declare to have no conflicts of interest.

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3. Review of the literature published since March 2018

In order to provide an accurate and up-to-date representation of the current state of aggression research, it is necessary to review the literature that has been published after the above article in March 2018. In this section, the peer-reviewed literature published between 2018 and October 2019 was identified using Google Scholar and Web of Science. The method of selecting the literature was the same as that employed in the published article. 66 new articles were identified using the search terms 'Pig' and 'Aggression' whilst 28 were identified using 'Sow' and 'Aggression'. The main findings of relevant articles are described, and an overview is provided in Table 1. Studies that did not specifically investigate the causes, effects or control of aggression at regrouping were excluded from this section, for example those studying aggression in stable groups (e.g. Boumans et al., 2018).

Relevant articles published over this time period have contributed to the literature regarding the negative impact of aggression on the immune response of sows (Schalk et al., 2018) and the stress response of weaners (Escribano et al., 2019); the expression of aggression as dependent upon conspecifics (Verdon et al., 2018); and several strategies to control aggression. Specific strategies that have received further research are pre-weaning

socialisation (Camerlink et al., 2018; Salazar et al., 2018; Verdon et al., 2019a; b; Weller et al., 2019), tranquilisers (Schwarz et al., 2018), and genetic solutions (Wurtz et al., 2018). Furthermore, the first steps in developing new strategies have been made based on the selection of breeding gilts from female-biased litters (Seyfang et al., 2018), creating satiety in sows as they are mixed (Greenwood et al., 2019), and the development of precision livestock farming technology to automatically detect aggression (Chen et al., 2018).

It is well-established that pre-weaning socialisation of pairs of litters can effectively reduce regrouping aggression at weaning, however recent research has made important steps forward in exploring the behavioural mechanisms behind this effect (Weller et al., 2019), the gap in knowledge regarding the long term impact of socialisation on aggression (Camerlink et al., 2018), and in addressing farmer concerns about the strategy (Camerlink et al., 2018; Salazar et al., 2018). Weller et al (2019) found that although socialised litters were more efficient than control litters at establishing dominance relationships in the resident-intruder test, this was not associated with greater experience of play behaviour in socialised litters. Camerlink et al (2018) compared pig behaviour in socialised groups to control groups not only at weaning (4 weeks old), but also when regrouped at eight weeks old.

At 8 weeks, socialised pigs displayed 19% fewer skin lesions, suggesting that the benefits of socialisation are sustained beyond weaning. Growth did not differ between the two conditions; however, sows of socialised litters displayed more teat damage on the day of weaning than control sows.

Furthermore, Salazar et al (2018) confirmed that the beneficial results of socialisation found in experimental settings can also be achieved in a large scale commercial pig farm. Piglets socialised at 7 and 14 days of age were less aggressive at weaning, and groups did not differ in body weight and growth rate after weaning (Salazar et al., 2018).

Whilst the impact of socialising litters in adjacent farrowing crates has been well studied, Verdon et al (2019a; b) studied the impact of socialising piglets in group lactation systems whereby multiple sows and litters are able to freely socialise in pens. Results revealed that piglets reared in group lactation systems were less aggressive at mixing than piglets reared in individual, conventional farrowing crates (Verdon et al., 2019a). No differences in aggressive behaviour occurred between piglets moved into group lactation systems at 7 days old compared to at 14 days old. Although there were benefits associated with reduced aggression and the expression of natural

maternal behaviours, there were costs associated with disrupted nursing behaviour and cross-suckling (Verdon et al., 2019b).

Another strategy to receive further research is the use of tranquilising drug azaperone. Schwarz et al (2018) provide further barriers to the use of this drug. In their study, 619 test sows administered azaperone immediately prior to regrouping displayed significantly delayed onset of estrus when compared to 1180 untreated controls. By increasing the number of non-productive days, azaperone treatment resulted in increased production costs to farmers (Schwarz et al., 2018).

Regarding genetic solutions, Wurtz et al (2018) identified that chromosome 11 contains a region explaining variation in the number of skin lesions following regrouping in a sample of 1093 pigs at three ages (weaning, growing / finishing, mature gilts). Although further exploration is required in order to determine if genes in this region are involved in the underlying biological control of aggression, the identification of a significant marker for the complex trait of aggression is a positive step forward. Therefore, recent publications support, rather than contradict, the findings outlined in the

literature review with regards to pre-weaning socialisation (Camerlink et al., 2018; Salazar et al., 2018), tranquilisers (Schwarz et al., 2018), and genetic solutions (Wurtz et al., 2018).

Finally, research has made initial steps in developing two newer aggression control strategies. First, Seyfang et al (2018) suggest that aggression at regrouping in sows may be reduced by selecting breeding gilts from female-biased litters. Their study revealed that gilts from male biased litters expressed greater lesion scores at weaning than gilts from female biased litters, and this is likely due to these females being masculinised by greater exposure to androgens in utero. However, it is currently unclear whether this effect continues into adulthood, and this strategy, therefore, requires further research (Seyfang et al., 2018). Second, Greenwood et al (2019) suggest that aggression at regrouping in sows may be reduced by creating satiety at mixing as this reduces competition for feed as a limited-resource. However, the authors concluded that different high fibre diets (standard diet at a high feeding level vs. diet containing 2.5% of lignocellulose) affect aggressive behaviour in different ways, and further research is required into the mechanics of sow satiety. Finally, the development of precision livestock farming (PLF) technology to recognise harmful social behaviour has received

increased attention in recent years (e.g. D'Eath et al., 2018), and Chen et al (2018) reported an algorithm to successfully recognise aggressive behaviour between growing pigs at regrouping. This technology has the capacity to improve the efficiency of behavioural detection, but is in the early stages of development (Chen et al., 2018)

Table 1. An overview of the literature regarding the control of aggression between pigs at regrouping published between 2018 and October

Strategy	Contribution to literature	Literature	2019.
Genetic solutions	Chromosome 11 contains a region explaining variation in the number of skin lesions following regrouping.	(Wurtz et al., 2018)	
Management			
Early life socialisation	Evidence that socialisation: is effective under commercial farming conditions; does not negatively affect piglet growth; can lead to sow teat damage; does not increase play behaviour.	(Camerlink et al., 2018; Salazar et al., 2018; Weller et al., 2019)	
Group lactation	Piglets reared in group lactation systems from 7 and 14 days old are less aggressive at mixing than piglets reared in farrowing crates. Costs arise due to disrupted nursing behaviour and cross-suckling.	(Verdon et al., 2019a; b)	
Tranquiliser (azaperone)	Sows administered azaperone displayed significantly delayed onset of estrus and therefore more unproductive days.	(Schwarz et al., 2018)	
Select breeding gilts from female-biased litters	Greater aggression displayed by gilts from male-biased litters than female-biased litters at regrouping.	(Seyfang et al., 2018)	
Creating satiety in sows at mixing	Aggression at regrouping in sows may be reduced by creating satiety at mixing by feeding a high fibre diet.	(Greenwood et al., 2019)	
Precision livestock farming			
Aggression detection technology	Algorithm successfully recognised aggressive behaviour between growing pigs at regrouping.	(Chen et al., 2018)	

4. Conclusions

This chapter reviewed the scientific literature on pig aggression and in doing so (1) identified the wide variety of aggression control strategies proposed by research, and (2) identified the most promising strategies to be the use of pheromones, genetic solutions, enhancing levels of tryptophan in the feed, housing pigs in large social groups, providing sufficient space and allowing litters to mix prior to weaning. Furthermore, this chapter (3) found limited evidence in the industry literature for the uptake of aggression research in practice and (4) discussed the range of likely reasons for this, including low prioritisation of the problem, the practicalities of implementation, ineffective communication of research to the farming community and economic factors. In order to bridge the gap between aggression research and practice, a better alignment between research and industry interests is required, and this is the subject of the following thesis. Over the following five research chapters I involve farmers in aggression research. By identifying the wide range of internal and external factors which influence farmer behaviour regarding aggression I hope to identify targets for initiating a change in practice (**Chapters 3, 4 and 5**). By calculating farmers' willingness to pay for reductions in aggression, and the economic consequences of investing in

specific aggression control strategies, I hope to identify cost-effective solutions based on farmer demand (**Chapter 6 and 7**).

Chapter 3: Belief in pigs' capacity to suffer: an assessment of pig farmers, veterinarians, students and citizens

1. Introduction

The concept of animals being sentient, or capable of experiencing positive and negative affective states, has been a topic of great interest and strong debate throughout history. Animal sentience underpins moral concern for animals, and recent research has established that human perceptions of animal sentience are flexible. Human omnivores reduce their perception of livestock capacity to suffer as a psychological defence in order to avoid discomfort associated with meat-eating. This chapter provides the first investigation into whether farmers reduce their perception of pigs' capacity to suffer in order to reduce discomfort associated with meat-production. This is important because farmers who ascribe their animals less capacity to suffer are unlikely to make animal welfare improvements. This may, therefore, contribute to the non-financial reasons behind the generally slow progress in resolving animal welfare issues, such as aggression. This chapter consists of a brief history of views of animal sentience (Section 2), a description of how these views influence the treatment of animals (Section 3), a journal article investigating perceptions of pig sentience in farmers, students, veterinarians and citizens (Section 4), and concluding remarks (Section 5).

2. A brief history of the views of animal sentience

This thesis defines an ‘animal’ as any living organism which feeds on organic matter, typically having specialised sense organs and a nervous system’ (Oxford English Dictionary, 2010). There is evidence that animal sentience, particularly among vertebrate species, has been accepted among lay people for hundreds of years. However, there has been much disagreement amongst philosophers and scientists (Duncan, 2006). In philosophy, there is a clear line of argument throughout history, reaching as far back as Aristotle (384–322 BC), that all non-human animals are incapable of experiencing subjective emotional states. This was most famously promoted by Cartesian philosopher and vivisectionist Rene Descartes (1596-1650) who saw non-human animals as ‘automata’, without emotions or inner subjective mental worlds. Under the Cartesian school of thought, non-human animal behaviour was merely mechanistic. It was not until the 18th century that Cartesian philosophy was overshadowed, and philosophers began to argue that at least some non-human animal species are capable of experiencing emotions (Duncan, 2006; Proctor, 2012). Today, the philosophical argument for animal sentience is particularly promoted by Peter Singer (1946-present). Singer argues that animals are sentient beings, and the failure of humans to

provide equal consideration to the interests of all sentient beings is 'speciesism' (Singer, 1975).

Amongst scientists, there is evidence from throughout the 19th century that emotions were believed to be experienced by animals, particularly as adaptations which allowed them to react appropriately to environmental pressures, and thus promote survival (Spencer, 1855; Darwin, 1872).

However, it was not until the last quarter of the 20th century that a surge of productivity occurred in studying how animals feel. Reluctance to consider emotions scientifically was predominantly due to the behaviourist School of Psychology (founded in 1913), which vehemently opposed non-human animal consciousness and capacity to suffer. Behaviourism dominated the study of behaviour for around 70 years and, as it saw any mention of 'feelings' or 'suffering' as unscientific, it had a strong, inhibiting effect on the study of non-human animal emotions. However, the grip of behaviourism waned following the publication of Ruth Harrison's 'Animal Machines' (Harrison, 1964) and the subsequent UK government's Brambell report (Brambell, 1965), which both emphasised that animal feelings are important in livestock production. As a result, the past few decades have seen a rapid increase in the scientific study of non-human animal emotions, which are now a topic of great interest to scientists. Animal welfare as a complex and

multifaceted issue; comprising of emotional state, health and freedom to perform natural behaviour. Some scientists emphasise that feelings are the only thing that matter to animal welfare (Duncan, 2004).

A paradox exists whereby at the heart of animal welfare science is animals' capacity to experience emotions, yet it is impossible to observe the emotional experiences of animals directly and, therefore, to be certain of what they feel (Dawkins, 2015). As a result, scientists must make inferences from a wide variety of observable, indirect indicators relating to the animals physiological and behavioural characteristics. For example, activation of the autonomic and endocrine systems can be used as rough physiological indicators of fear, anger and frustration, although it is important to note that these systems can also be activated in anticipation of events such as mating and food, which are not typically associated with negative emotions (Dawkins, 2015). The presence of nociceptors indicates that animals have the physiological capacity to detect pain (Sneddon, 2009), whilst traumatic neuromas point towards the experience of pain (Sandercock et al., 2016), although it is important to note that this neurological evidence does not prove conscious awareness of pain. The release of the hormone oxytocin occurs during positive tactile contact such as nursing, mating, and grooming and is presumed to indicate positive emotions in animals (Uvnas-Moberg, 1998).

Behavioural indicators of animal emotions include facial expression (Leach et al., 2012), approach / avoidance behaviour (Fraser and Matthews, 1997), abnormal behaviours such as stereotypies (Mason, 1991) and the self-administration of pain relieving medication (Danbury et al., 2000). It is a popular belief that invertebrates have a reduced capacity to experience suffering in comparison to vertebrates (Sherwin, 2010). However, various invertebrate species, such as cockroaches, flies and slugs exhibit behavioural and physiological responses indicative of pain; and it is currently impossible to know which animal species are and are not capable of suffering (review article: Sherwin, 2001). Although research has predominantly focussed on the experience of negative emotions, there has been an increasing interest in the experience of positive emotions over the last decade (e.g. Yeates and Main, 2008; Vigors, 2019).

3. Belief in animal sentience underpins behaviour regarding animal welfare

Belief in animal sentience is important in determining human attitudes and behaviour towards animals (Knight et al., 2004; Knight et al., 2009; Proctor, 2012). The knowledge regarding animal sentience which has developed rapidly over recent decades has had significant implications for the ethics of

food production and how we treat animals (Proctor, 2012; Cornish. et al., 2016). For example, many countries now enforce legislation which acknowledges most non-human animal species as sentient beings and protects them from unnecessary suffering. Today, most people perceive non-human animals, particularly vertebrate species, as capable of suffering, and find animal suffering emotionally disturbing (Braithwaite and Braithwaite, 1982; Schröder and McEachern, 2004). However, it is established that these perceptions of non-human animal sentience are flexible and depend on species (pet versus livestock species) and circumstances (e.g. recent consumption of animal products) (Loughnan et al., 2010; Bratanova et al., 2011; Bastian et al., 2012; Bastian and Loughnan, 2017). This is due to the ‘meat-paradox’ which refers to the fact that most people like eating meat, but have an aversion to animal suffering. As a result, omnivores employ a range of techniques to reduce psychological discomfort associated with eating meat, and one of these strategies is to ascribe livestock species diminished mental states necessary to experience suffering (Loughnan et al., 2010; Bilewicz et al., 2011; Bratanova et al., 2011; Bastian et al., 2012; Wilkins et al., 2015). However, no research to date has investigated whether farmers adopt a similar strategy to cope with discomfort associated with meat production. The following publication provides the first investigation into how farmers deal with the meat paradox by assessing their perceptions of pigs’ capacity to

suffer. Farmers' perceptions of pigs' capacity to suffer are compared to a species that they do not farm (cows) and to two species typically considered pets (cats and dogs). Furthermore, these perceptions are compared to those of participants with experience of working with pigs (specialised pig veterinarians) and without experience (agricultural students, animal science students and citizens unrelated to agriculture). Belief in pigs' capacity to suffer has important implications for farmers' willingness to improve animal welfare by controlling issues such as aggression.

4. Journal article

Declaration

Rachel Peden designed this study, collected data, analysed data and wrote the original version of the manuscript. Simon Turner and Laura Boyle helped to collect data at farmer discussion groups. Simon Turner provided advice on appropriate statistical analysis. Simon Turner, Faical Akaichi, Irene Camerlink, Steve Loughnan and Laura Boyle provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to external peer review comments, prepared the response letter for the journal and was the corresponding author. Inclusion of this publication complies with copyright laws. Permission from co-authors was obtained regarding the inclusion of this article in the current thesis.

Belief in Pigs' Capacity to Suffer: An Assessment of Pig Farmers, Veterinarians, Students, and Citizens

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ABSTRACT Intensive animal production practices lead to animal suffering worldwide. This study examined whether farmers cope with the negative impact of farming practices on their animals by ascribing them less capacity to suffer compared with other species. Most people like eating meat but find animal suffering emotionally disturbing. Human omnivores employ a variety of strategies to navigate this “meat paradox,” and one of these is to reduce their perception of animals' capacity to suffer. Psychological defenses associated with meat-eating have been widely researched, but this study provides the first investigation into how these are employed amongst those involved in meat production and focusses on intensive pig producers as an example. Seventy-six pig farmers reported their belief in pigs' capacity to experience pain, hunger, fear, and boredom in a paper-based survey employing visual analogue scales. Their responses were compared with their perceptions of livestock that they did not farm (cows) and two companion animal species (dogs and cats). These results were compared with people who had similar experience of working with pigs (15 specialized pig veterinarians) and those who had no experience of pigs (23 agricultural students, 22 animal science students, and 58 citizens unrelated to agriculture). The results of the 194 responses provide evidence to suggest that the pig farmers did not ascribe their animals a diminished capacity to suffer. Rather, pig farmers expressed an enhanced belief in pigs' capacity to experience

hunger. All comparison groups expressed widespread belief in each species' capacity to suffer. Nevertheless, dogs were the species judged to be most capable of suffering, and animal science students gave the highest suffering scores overall. Farmers are directly responsible for the welfare of their animals, and further investigation into the psychological and behavioral strategies of farmers may provide insight into non-financial reasons behind the generally slow progress in improving animal welfare.

Keywords: animal sentience, animal welfare, cognitive dissonance, farmers, human–animal interaction



Animal production is at an all-time high. World pork production doubled between 1985 and 2016 (Food and Agriculture Organization of the United Nations., 2018). Today over 1.3 billion pigs are slaughtered worldwide each year and production is expected to continue rising (OECD/FAO, 2018). Growing demand for animal products over recent decades has been driven by the growing human population (Gelbard, Haub, & Kent, 1999; Godfray et al., 2010) and by the growing consumption of meat as a result of increased incomes and urbanization (Delgado, 2003; Steinfeld, Wassenaar, & Jutzi, 2006). Demand for low-cost meat has driven intensification in some livestock sectors and low-input extensification in others (Steinfeld et al., 2006). Across the modern livestock sectors, economic market-driven constraints limit options for safeguarding animal welfare where this requires increases in fixed or variable costs. In the global commercial pig industry, the majority of animals are housed in indoor, intensive units with high stocking densities. These systems are sophisticated and highly engineered; designed for efficiency and maximum production at minimum cost. Nevertheless, such intensive systems are associated with numerous threats to animal welfare. This paper examines whether pig farmers cope with the impact of the farming system on their animals by ascribing them less capacity to suffer compared with other species.

Although intensive systems offer some welfare advantages (e.g., easy health inspection, controlled climate) pigs experience injuries, pain, and stress caused by aggression (Peden, Turner, Boyle, & Camerlink, 2018), tail biting (D'Eath et al., 2016), lameness (KilBride, Gillman, & Green, 2009), routine husbandry procedures such as tail docking (Wilson, Holyoake, Cronin, & Doyle, 2014), and lack of opportunity to display innate behaviors (Taylor, Main, Mendl, & Edwards, 2010). Breeding sow welfare is further challenged by the use of farrowing crates, the continued use of sow stalls in some countries (Baxter, Lawrence, & Edwards, 2012), and chronic hunger as a result of restricted diets (D'Eath, Jarvis, Baxter, & Houdijk, 2018; Meunier-Salaun, Edwards, & Robert, 2001). Therefore, adjustments to production practices to meet the growing consumer demand for low-cost meat is a leading cause of pig suffering worldwide.

Meanwhile, affectionate relationships between humans and companion animals are a fundamental part of contemporary life (Walsh, 2009). Pet ownership is increasing (European Pet Food Federation, 2016) and pet animals are commonly considered to be family members (Cohen, 2002). Most people find animal suffering emotionally disturbing and disapprove of harming animals (Braithwaite & Braithwaite, 1982; Schröder & McEachern, 2004). However, this disapproval rarely translates into ethical buying behavior (Carrington, Neville, & Whitwell, 2010; Schröder & McEachern, 2004; Te Velde, Aarts, & Van Woerkum, 2002). Therefore, many people hold inconsistent but simultaneous beliefs regarding animals: they have an aversion to harming animals but like animal products (Bastian & Loughnan, 2017; Loughnan, Haslam, & Bastian, 2010).

The psychological conflict between people's dietary preference for meat and their moral response to animal suffering is termed "the meat paradox" (Bastian & Loughnan, 2017;

Loughnan et al., 2010). The inconsistencies between beliefs and behavior result in an unpleasant emotional state known as cognitive dissonance, whereby people become motivated to alter one of the inconsistent elements (Festinger, 1957). Some people alter their behavior by avoiding eating meat, and indeed most vegetarians in Western societies report moral concern for animals as a major factor in their dietary choice (Fox & Ward, 2008; Hussar & Harris, 2010). However, most people continue to eat meat. Whilst some make ethical buying decisions, many do not and employ a number of psychological defenses in order to reduce cognitive dissonance.

One of the main defenses employed by humans eating meat is the mental disengagement of meat from animal. Physical distance and lack of transparency in animal production allows consumers to avoid considering how animals are farmed (Hoogland, de Boer, & Boersema, 2005; Schröder & McEachern, 2004). Moreover, meat products are marketed, packaged, and sold in a way that does not remind the consumer of the animal from which it came (Hoogland et al., 2005); this reduces consumer empathy and disgust (Kunst & Hohle, 2016). In some countries the association is broken further through the use of language; for example, we eat “beef” and “pork” instead of cattle and pigs (Bastian & Loughnan, 2017). Therefore, disengagement from animal production allows consumers to buy and eat meat frequently with little or no discomfort (Bastian & Loughnan, 2017) or consideration of livestock suffering (Carrington et al., 2010). However, consumers are not always able to avoid the link between meat and animals, and when forced to consider the animal-meat link one resolution is to alter beliefs about livestock. Several studies reveal that livestock are ascribed diminished mental states necessary to experience suffering (Bastian, Loughnan, Haslam, & Radke, 2012; Bilewicz, Imhoff, & Drogosz, 2011; Bratanova, Loughnan, & Bastian, 2011; Loughnan et al., 2010; Wilkins, McCrae, & McBride, 2015). The capacity to suffer has long been emphasized as the basis of moral concern for animals. This was famously articulated by philosopher Jeremy Bentham when he stated: “The question is not, Can they reason? nor, Can they talk? but, Can they suffer?” (1823). Therefore, by denying livestock the capacity to suffer, many omnivores restrict moral concern for animals which allows them to eat animals without experiencing discomfort.

Farmers are a fundamental component of livestock production systems: they are responsible for all aspects of animal husbandry, including the routine administration of painful procedures such as tail docking and teeth clipping. Therefore, farmers have heightened awareness of animal suffering and, unlike consumers, they are unable to rely on the mental disengagement of meat from animal. This regular, direct exposure and participation in animal production may leave farmers particularly susceptible to high levels of cognitive dissonance. Psychological defenses employed to resolve dissonance have been widely researched in consumers without a farming background. However, no research has investigated how these psychological defenses are employed by farmers in spite of the important implications for farm animal welfare. Specifically, farmers who ascribe their animals less capacity to suffer may be less inclined to make animal welfare improvements, and this may contribute to the generally slow progress in improving animal welfare (Millman, Duncan, Stauffacher, & Stookey, 2004; Peden et al., 2018). This study provides the first investigation into dissonance-reducing strategies employed by farmers and focusses on intensive pig producers as an example. We hypothesized: 1) that pig farmers will ascribe pigs diminished mental states necessary to experience suffering compared with other species; and 2) that pig farmers will ascribe pigs with less capacity to suffer compared with citizens unrelated to pig husbandry.

Methods

Overview

The current study investigated pig farmers' perceptions of pigs' capacity to suffer through a paper-based questionnaire. This was compared with that of cows (a livestock species that they do not farm) and cats and dogs (companion animal species). Moreover, farmers' responses were compared with those of animal science students, agricultural students, specialized pig veterinarians, and citizens unrelated to agriculture.

Questionnaire

The questionnaire consisted of two parts. The first part collected information on age, gender, location (England, Scotland, Wales, Northern Ireland, Republic of Ireland), and experience of working with pigs. Farmers were also asked for their role on the farm, students were asked for their course title and year of study, and citizens were asked for their occupation. The second part was on animal suffering. The questions were designed and used in previous research with students (Paul & Podberscek, 2000) and measured participants' beliefs in the capacity of each of four species (dogs, cats, pigs, cows) to feel the sensations of hunger and pain and the emotions of fear and boredom. These sensations and emotions provide a brief but representative assessment of participants' beliefs in animals' capacity to experience suffering and are relevant to the challenges imposed by commercial pig production. Participants indicated their responses by placing a vertical line at the point they felt most appropriate on a 100 mm visual analogue scale (VAS) that ranged from "no, not at all" to "yes, in a very similar way to people." Scores were obtained by measuring the distance from the left end of the response line to the center of the respondent's line. This process generated individual scores for hunger, pain, fear, and boredom for each of the four domestic species. The survey was piloted with three pig farmers and seven researchers and amended according to their feedback regarding the wording and appropriateness of questions. The final version of the questionnaire received internal ethical approval from the Human Ethical Review Committee at the University of Edinburgh. Informed consent was obtained from all participants.

Recruitment

Participants were recruited between January 2017 and June 2018. Seventy-seven pig farmers were recruited at farmer events held by Scotland's Rural College ($n = 21$), Teagasc ($n = 27$) and the Agricultural and Horticultural Development Board (AHDB) Pork ($n = 29$). Specialized pig veterinarians ($n = 16$) were recruited at the same farmer events ($n = 11$) and through snowball sampling ($n = 5$) whereby veterinarian participants recruited other veterinarians. Snowball sampling is an established technique for recruiting hard-to-reach or specialized demographics (Babbie, 2010). We recruited fully qualified specialized pig veterinarians rather than veterinary students as previous research employing the same questionnaire found that veterinary students change their perceptions over the course of their studies (Paul & Podberscek, 2000). Furthermore, veterinarians provide an interesting comparison group owing to their comparable years' experience working in the pig industry as the farmers. Undergraduate students of animal science ($n = 24$) and agriculture ($n = 32$) courses were recruited following scheduled lectures and field trips held at Scotland's Rural College. The student populations provide interesting comparison groups because of their knowledge of farming and animals and lack of direct work experience with pigs. Moreover, the students' perceptions of animals' capacity to suffer are important as they are likely to work with animals in the future. As a control group, 66 citizens unrelated to agriculture were recruited through snowball sampling by one staff

member and six PhD students. They recruited friends and relatives in their hometowns to fill out the questionnaire and these people in turn recruited further participants. It is possible that citizens shared some values with researchers which may have influenced their results. However, this method of recruitment was used in previous published research studying attitudes toward animal welfare (You, Li, Zhang, Yan, & Zhao, 2014) and allowed us to recruit people from across the UK and Ireland who did not know the purpose of the study. Furthermore, this method of recruitment avoided participant self-selection based on interest in the study content (e.g., it is likely that only participants interested in animals would respond to advertisements). Citizens unrelated to agriculture provided an important comparison group as they had no specialization or experience within the pig industry.

Demographics of the Final Sample

Two applied animal science students, nine agriculture students, and seven citizens were eliminated from the analysis due to reporting previous experience working with pigs. One farmer, one specialized pig veterinarian, and one citizen were also eliminated due to missing answers. In total, 194 participants were included (see Table 1 for participants' age, gender, and experience working with pigs).

Pig farmers ($n = 76$) were located in England ($n = 28$), Scotland ($n = 21$), and the Republic of Ireland ($n = 27$). Farm size varied widely (Table 2) which is consistent with the structure of the industry (AHDB, 2014, 2015). Farmers were employed in a range of roles on the farm (Table 1) and were roughly representative of UK agricultural workers who are mainly male with a median age of 59 years (Defra, 2017). Applied animal science students ($n = 22$) were all

Table 1. Participants' age, gender, and experience of working with pigs according to their occupation and role on farm.

Occupation	Role on Farm	Mean Years' Experience (SD, range)	Mean Age in Years (SD, range)	Female	Male
Farmer ($n = 76$)	Owner ($n = 25$)	27.4 (9.9, 10–45)	47.2 (8.8, 30–61)	2.6% ($n = 2$)	30.3 % ($n = 23$)
	Manager ($n = 12$)	26.4 (13.0, 1–50)	50.2 (11.4, 28–68)	1.3% ($n = 1$)	14.5% ($n = 11$)
	Contract ($n = 7$)	22.4 (13.0, 5–40)	43.4 (17.6, 18–64)	0% ($n = 0$)	9.2% ($n = 7$)
	Worker ($n = 30$)	6.7 (8.0, 1–42)	33.2 (10.3, 18–55)	4.0% ($n = 3$)	35.5% ($n = 27$)
	Retired ($n = 2$)	52.5 (17.7, 40–65)	81.5 (0.7, 81–82)	0% ($n = 0$)	2.6% ($n = 2$)
	All roles	19.5 (15.0, 1–65)	42.7 (14.2, 18–82)	7.9% ($n = 6$)	92.1% ($n = 70$)
Specialised Pig Veterinarian ($n = 15$)	—	14.3 (15.0, 0.75–40)	41.3 (14.6, 25–66)	66.7% ($n = 10$)	33.3% ($n = 5$)
Applied Animal Science Student ($n = 22$)	—	—	23.1 (3.0, 22–36)	81.8% ($n = 18$)	18.2% ($n = 4$)
Agriculture Student ($n = 23$)	—	—	22.4 (1.7, 21–29)	47.8% ($n = 11$)	52.2% ($n = 12$)
Citizens Unrelated to Agriculture ($n = 58$)	—	—	52.0 (16.8, 19–88)	70.7% ($n = 41$)	29.3% ($n = 17$)

Table 2. Mean number of pigs kept at each stage of production at any one time, range, and standard deviation (*SD*). The number of farmers who kept pigs at the specified stage of production is given in parentheses.

Stage of Production	Mean (<i>n</i>)	Range	<i>SD</i>
Weaners	1918.0 (51)	150–10,000	1857.0
Growers	2493.5 (42)	150–30,000	4739.0
Finishers	3429.7 (48)	100–38,000	5914.0
Sows	1164.2 (66)	40–13,500	2297.9

based in Scotland and studying at Scotland's Rural College (SRUC) and were predominantly female (Table 1). This was observed previously in animal science student groups (Heleski & Zanella, 2006). Fourteen were in the third year and eight were in the fourth and final year of their course. Agriculture students ($n = 23$) were all based in Scotland and studying at SRUC. Twenty were in the third year and three were in the fourth year of their course. Specialized pig veterinarians ($n = 15$) were based in Scotland ($n = 5$), England ($n = 9$), and the Republic of Ireland ($n = 1$). Citizens unrelated to agriculture ($n = 58$) were based in Scotland ($n = 12$), England ($n = 40$), and the Republic of Ireland ($n = 6$). They were employed in a range of industries which roughly fell into a number of categories: education ($n = 3$), childcare ($n = 3$), administration ($n = 7$), management ($n = 5$), beauty therapy ($n = 4$), skilled trade/labor ($n = 7$), engineering ($n = 2$), marketing/design ($n = 3$), healthcare ($n = 8$), and being retired ($n = 16$). The sample is roughly representative of the UK population where 75.6% are employed across a range of industries (Office for National Statistics, 2018) and 18% exceed traditional working age (Office for National Statistics, 2017); however, our sample was skewed towards females (Table 1).

Statistical Analysis

All statistical analyses were carried out using SPSS Version 25 (Armonk, NY, USA). Residual maximal likelihood (REML) analysis was used to analyze the data as it does not require a balanced design and is well-suited for studies with unequal group sizes, such as this one. Furthermore, REML allowed us to control for extraneous variables (gender, age, and location). Four REML models were run to investigate the factors that are associated with scores for species' ability to experience hunger, pain, fear, and boredom. These were treated as four separate response variables. Fixed effects in the models were gender (male, female), age, location (England, Scotland, Ireland), species (dog, cat, cow, pig), and occupation (farmer, specialized pig veterinarian, applied animal science student, agriculture student, citizen unrelated to agriculture). It was important to include gender, age, and location first in each model in order to control for the important demographic differences between our comparison groups. To test hypotheses 1 and 2, the interactions between occupation and species were investigated. If the hypotheses were met we would expect an interaction to occur and that the effect should reside with farmers devaluing pigs in comparison with other species (hypothesis 1) and citizens unrelated to agriculture (hypothesis 2). Non-significant interactions and fixed effects were removed and the model re-run in order to maximize our ability to robustly test the effect of the remaining terms in the model. Inspection of the Akaike information criterion (AIC) values confirmed that the inclusion of non-significant terms did not improve model fit.

We detected a significant interaction between species and occupation for hunger score and investigated this further by running five one-way repeated measures ANOVAs to explore

the effect of species (dog, cat, pig, cow) on hunger score for farmers, specialized pig veterinarians, agriculture students, applied animal science students, and citizens unrelated to agriculture (further investigating hypothesis 1). We also ran four one-way ANOVAs to explore the effect of occupation (farmers, specialized pig veterinarians, agriculture students, applied animal science students, citizens unrelated to agriculture) on hunger scores for dogs, cats, cows, and pigs (further investigating hypothesis 2). Although the main effects of occupation, species, gender, age, and location were not directly related to our hypotheses, significant main effects were followed up with post-hoc analyses; the results are reported in order to aid interpretation of the data and contribute to the literature regarding human perceptions of animals. All post-hoc analyses were conducted using least significant difference (LSD) tests, with Bonferroni adjustments made for multiple comparisons. Results were considered significant at $p < 0.05$.

Results

Mean judgements of animal capacity to experience hunger, pain, fear, and boredom for each occupation and species are in Table 3.

Test of Hypotheses

To test hypotheses 1 and 2, the interactions between occupation and species were investigated. There were no significant interactions between occupation and species on scores for pain, fear, and boredom, indicating that the effect of species on these scores did not depend on occupation. There was a significant interaction between occupation and species for hunger score (Table 4); ANOVA was employed to investigate if this interaction was determined by species (H_1) and occupation (H_2).

Test of Hypothesis 1: One-way repeated measures ANOVAs revealed a significant effect of species on hunger score for farmers ($F_{(3, 225)} = 5.626, p < 0.01$) and citizens unrelated to agriculture ($F_{(3, 171)} = 9.276, p < 0.0001$). Farmers assigned pigs a greater capacity to experience hunger than dogs (mean difference = 5.3; $SE = 1.6$; 95% CI = 0.9 to 9.8; $p < 0.05$), cats (mean difference = 6.4; $SE = 1.7$; 95% CI = 1.7 to 11.1; $p < 0.01$), and cows (mean difference = 4.0; $SE = 1.5$; 95% CI = 0.0 to 8.0; approaching significance at $p = 0.051$). Citizens unrelated to agriculture judged cows as less capable of experiencing hunger than dogs (mean difference = 11.1; $SE = 2.6$; 95% CI = 3.9 to 18.2; $p < 0.01$), cats (mean difference = 8.7; $SE = 2.5$; 95% CI = 1.9 to 15.4; $p < 0.01$), and pigs (mean difference = 6.0; $SE = 2.1$, 95% CI = 0.2 to 11.9; $p < 0.05$). All other occupations gave comparable hunger scores to each species ($p > 0.05$). Therefore, farmers did not diminish scores for pigs compared with other species; this does not support our first hypothesis (H_1 : Pig farmers will ascribe pigs diminished mental states necessary to experience suffering as compared with other species).

Test of Hypothesis 2: One-way ANOVAs revealed a significant effect of occupation on hunger scores for dogs ($F_{(4, 189)} = 2.832, p < 0.05$), cats ($F_{(4, 189)} = 3.076, p < 0.05$), cows ($F_{(4, 189)} = 4.739, p < 0.01$), and pigs ($F_{(4, 189)} = 3.185, p < 0.05$). Post-hoc analysis revealed that these significant effects were determined by applied animal science students judging dog capacity for hunger to be greater than that scored by farmers (mean difference = 11.5, $SE = 3.6$, 95% CI = 1.2 to 21.7, $p < 0.05$); cat capacity for hunger to be greater than that scored by farmers (mean difference = 12.2, $SE = 3.8$, 95% CI = 1.3 to 27.8, $p < 0.05$) and agriculture students (mean difference = 14.3, $SE = 4.7$, 95% CI = 0.9 to 27.8, $p < 0.05$); and cow (mean difference = 17.6, $SE = 4.4$, 95% CI = 5.2 to 30.1, $p < 0.01$) and pig (mean

Table 3. Mean (SD) hunger, pain, fear, and boredom scores according to occupation and species. All scores were measured on a 100 mm visual analogue scale.

Emotion/ Sensation	Occupation	Species				
		Dogs	Cats	Pigs	Cows	All Species
<i>Hunger</i>	Farmers	83.5 (15.7)	82.4 (17.0)	88.9 (9.9)	84.9 (15.3)	85.0 (14.8)
	Specialised pig veterinarians	89.7 (12.3)	86.3 (14.4)	87.5 (14.3)	82.8 (18.7)	87.3 (14.7)
	Applied animal science students	95.0 (5.3)	94.7 (5.8)	94.3 (5.5)	94.5 (6.2)	94.6 (5.6)
	Agriculture students	85.7 (18.0)	80.3 (23.0)	88.1 (11.0)	88.1 (10.5)	85.6 (16.5)
	Citizens unrelated to agriculture	88.0 (15.5)	85.6 (13.6)	82.9 (19.4)	76.9 (23.9)	83.5 (18.7)
	All occupations	86.9 (15.2)	84.8 (16.2)	87.5 (13.9)	83.8 (18.2)	85.8 (15.9)
<i>Pain</i>	Farmers	87.8 (10.7)	84.6 (14.5)	86.3 (17.2)	81.3 (17.6)	85.1 (15.3)
	Specialised pig veterinarians	90.9 (10.5)	87.3 (15.1)	86.5 (14.4)	83.8 (18.0)	87.8 (14.4)
	Applied animal science students	95.3 (5.1)	94.5 (5.6)	92.7 (6.1)	92.4 (8.3)	93.7 (6.4)
	Agriculture students	87.8 (10.9)	86.1 (15.8)	86.9 (12.3)	87.8 (12.0)	87.2 (12.7)
	Citizens unrelated to agriculture	91.4 (8.1)	87.6 (13.2)	81.9 (19.7)	81.0 (21.0)	85.5 (16.6)
	All occupations	90.0 (9.7)	87.0 (13.8)	85.8 (16.6)	83.5 (17.7)	86.6 (14.9)
<i>Fear</i>	Farmers	86.2 (13.4)	80.6 (19.6)	84.7 (17.5)	78.7 (21.2)	82.6 (18.2)
	Specialised pig veterinarians	87.7 (13.1)	85.7 (15.0)	82.9 (18.2)	81.7 (19.3)	84.8 (16.2)
	Applied animal science students	94.0 (6.8)	93.3 (6.4)	92.5 (5.7)	92.3 (7.8)	93.0 (6.6)
	Agriculture students	86.0 (12.9)	83.0 (17.8)	84.4 (18.9)	85.7 (14.1)	84.8 (15.9)
	Citizens unrelated to agriculture	87.1 (14.9)	79.5 (23.4)	76.6 (22.5)	75.6 (24.4)	79.9 (21.7)
	All occupations	87.4 (13.3)	82.4 (19.6)	83.0 (19.0)	80.4 (20.8)	83.4 (18.4)
<i>Boredom</i>	Farmers	77.5 (21.9)	69.6 (26.6)	78.8 (24.4)	64.0 (29.6)	72.7 (26.2)
	Specialised pig veterinarians	85.1 (18.6)	69.6 (30.9)	80.5 (19.1)	58.3 (27.5)	74.2 (25.7)
	Applied animal science students	88.7 (13.9)	78.0 (26.4)	80.5 (21.3)	73.5 (24.3)	80.2 (22.3)
	Agriculture students	79.1 (22.6)	70.6 (28.9)	77.3 (24.9)	70.9 (28.4)	74.5 (26.2)
	Citizens unrelated to agriculture	77.1 (22.6)	64.5 (28.9)	57.0 (28.3)	54.3 (29.6)	62.9 (28.7)
	All occupations	79.4 (21.4)	69.1 (27.9)	72.4 (26.8)	62.6 (29.3)	70.9 (27.1)

difference = 11.3, $SE = 3.4$, 95% CI = 1.6 to 21.0, $p < 0.05$) capacity for hunger to be greater than that ascribed by citizens unrelated to agriculture. Therefore, farmers did not diminish scores for pigs when compared with citizens unrelated to agriculture; this does not support our second hypothesis (H_2 : Pig farmers will ascribe pigs with less capacity to suffer compared with citizens unrelated to pig husbandry).

Tests of Main Effects

The results of main effects in each REML model are reported here.

Main Effects of Occupation: There were significant main effects of occupation on scores for hunger, pain, fear, and boredom across all species (Tables 3 and 4). Applied animal science students scored the capacity for hunger higher than farmers (mean difference = 6.9, $SE = 2.0$,

Table 4. Results of four residual maximum likelihood (REML) models investigating the effects of gender, age, location, species, and occupation on scores for 1) hunger, 2) pain, 3) fear, and 4) boredom. Non-significant effects and interactions were removed from each model and the model re-run until the simplest model was achieved.

Dependent Variables	Independent Variables					
	Main Effects					Interaction
	Gender	Age	Location	Species	Occupation	Species x Occupation
Hunger Score	ns	$F = 11.638^{**}$	ns	ns	$F = 4.525^{**}$	$F = 1.850^*$
Pain Score	$F = 4.983^*$	ns	$F = 4.883^{**}$	$F = 5.797^{***}$	$F = 4.611^{**}$	ns
Fear Score	ns	ns	ns	$F = 5.281^{**}$	$F = 9.235^{***}$	ns
Boredom Score	$F = 5.467^*$	$F = 11.824^{**}$	ns	$F = 14.416^{***}$	$F = 4.311^{**}$	ns

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = non-significant.

95% CI = 1.2 to 12.7, $p < 0.01$), agriculture students (mean difference = 9.2, $SE = 2.3$, 95% CI = 2.7 to 15.6, $p < 0.01$), and citizens unrelated to agriculture (mean difference = 7.2, $SE = 2.3$, 95% CI = 0.7 to 13.6, $p < 0.05$); pain to be higher than was scored by farmers (mean difference = 8.5; $SE = 2.2$, 95% CI = 2.2 to 14.7, $p < 0.01$) and citizens unrelated to agriculture (mean difference = 8.8, $SE = 2.1$; 95% CI = 2.8 to 14.8, $p < 0.001$); and fear to be higher than was scored by farmers (mean difference = 10.5, $SE = 2.2$; 95% CI = 4.3 to 16.6, $p < 0.001$), specialized pig veterinarians (mean difference = 8.5, $SE = 3.0$, 95% CI = 0.0 to 17.0, $p < 0.05$), agriculture students (mean difference = 8.2, $SE = 2.7$, 95% CI = 0.7 to 15.8, $p < 0.05$), and citizens unrelated to agriculture (mean difference = 13.3, $SE = 2.3$, 95% CI = 7.0 to 19.7, $p < 0.001$). Applied animal science students also scored the capacity for boredom higher than any other group (Table 3), but once differences in age, gender, and location were accounted for in the statistical model their responses were comparable to all other groups ($p > 0.05$). Farmers gave higher boredom scores than citizens unrelated to agriculture (mean difference = 10.5, $SE = 2.8$, 95% CI = 2.7 to 18.3, $p < 0.01$).

Main Effects of Species: There were significant main effects of species on scores for pain, fear, and boredom, but not hunger, across all occupations (Tables 3 and 4). Dogs received higher pain scores than cows (mean difference = 6.5, $SE = 1.5$, 95% CI = 2.6 to 10.4, $p < 0.001$) and pigs (mean difference = 4.2, $SE = 1.5$, 95% CI = 0.3 to 8.1, $p < 0.05$); higher fear scores than cats (mean difference = 5.1, $SE = 1.8$, 95% CI = 0.2 to 9.9, $p < 0.05$) and cows (mean difference = 7.1, $SE = 1.8$, 95% CI = 2.2 to 11.9, $p < 0.01$); and higher boredom scores than cats (mean difference = 10.3, $SE = 2.6$, 95% CI = 3.4 to 17.2, $p < 0.01$), cows (mean difference = 16.8, $SE = 2.6$, 95% CI = 9.9 to 23.7, $p < 0.001$), and pigs (mean difference = 7.0, $SE = 2.6$, 95% CI = 0.1 to 13.9, $p < 0.05$). Pigs received higher boredom scores than cows (mean difference = 9.9, $SE = 2.6$, 95% CI = 3.0 to 16.8, $p < 0.01$). Cats' boredom scores were comparable to those of both pigs and cows ($p > 0.05$).

Main Effects of Age, Gender, and Location: Females gave higher scores than males for pain (mean difference = 3.0, $SE = 1.3$, 95% CI = 0.4 to 5.6, $p < 0.05$) and boredom (mean difference = 5.5; $SE = 2.4$, 95% CI = 0.9 to 10.1, $p < 0.05$), but gender did not affect hunger or fear scores (Table 4). There were significant main effects of age on scores for hunger and boredom but not pain or fear (Table 4). These were determined by significant but weak negative correlations between age and hunger score ($r = -0.187$, $p < 0.001$) and age and boredom

score ($r = -0.202$, $p < 0.001$): older respondents regarded all species as less capable of experiencing hunger and boredom. Participants from Ireland scored the capacity for pain to be higher than those located in England (mean difference = 4.4, $SE = 1.6$, 95% CI = 0.6 to 8.3, $p < 0.05$) and Scotland (mean difference = 5.0, $SE = 1.7$, 95% CI = 0.8 to 9.2, $p < 0.05$), but location did not affect hunger, fear, or boredom scores (Table 4).

Discussion

In order to minimize psychological discomfort, some people who eat meat make ethical buying decisions whilst many mentally disengage *animals* from *meat* (Bastian & Loughnan, 2017; Hoogland et al., 2005; Schröder & McEachern, 2004). When forced to face this link, one resolution is for people to reduce their perception of animals' capacity to suffer (Bastian et al., 2012; Bilewicz et al., 2011; Bratanova et al., 2011; Loughnan et al., 2010; Wilkins et al., 2015) and hence their moral concern for animals. Farmers are unable to avoid the link between animals and meat, and this study provided the first investigation into whether they cope with the adverse effect of the farming system on their animals by ascribing them diminished capacity to suffer. The results do not support our hypothesis that pig farmers ascribe the species diminished mental states necessary to experience suffering.

Test of Hypotheses

There were no significant interactions between species and occupations for pain, fear, and boredom, indicating that the effect of species on these scores did not depend on occupation. Where a significant interaction did occur (hunger) it did not reside with farmers devaluing pigs in comparison with other species (hypothesis 1) and citizens unrelated to agriculture (hypothesis 2). In fact, farmers judged pigs as more capable of experiencing hunger than each of the other species. Sows are feed-restricted for management purposes and express their hunger through vocalizations and (redirected) feeding behavior (D'Eath et al., 2018). Farmers are therefore exposed daily to sows' chronic hunger (Tolkamp & D'Eath, 2016) and their responses may thus be influenced by knowledge about the animals' capacity to experience that sensation. Moreover, their response could be linked to greater empathy because of experience. Exposure and contact are known to enhance empathy between humans (Dovidio, Gaertner, & Kawakami, 2003; Pettigrew & Tropp, 2008); this has more recently been demonstrated in human–animal relationships (Morris, Knight, & Lesley, 2012). However, it is important to note that the specialized pig veterinarians had comparable years' experience working with pigs but no significant effects were detected for this group. Nevertheless, veterinarians are not responsible for animal husbandry and their exposure to sow hunger will therefore differ from farmers'. Scientists express widespread belief in the emotional lives of animals, including those that they use in their research (Knight, Vrij, Bard, & Brandon, 2009). Along with the results of the current study, this demonstrates that animal husbandry and the experimental use of animals can still be supported even when animals are perceived to be capable of suffering. Moreover, it fails to support an important prediction from current psychological theory: farmers will deny their animals more mind.

Effects of Occupation on Perceptions of Animals' Capacity to Suffer

Although respondents from all occupations expressed belief in animals' capacity to suffer, there were differences between groups in their attribution of each sensation/emotion. Even after controlling for demographic differences, applied animal science students gave higher scores than farmers, veterinarians, agriculture students, and citizens for fear; higher scores

than farmers and citizens for pain, and; higher scores than farmers, agriculture students, and citizens for hunger. Furthermore, animal science students judged dog capacity for hunger as greater than did farmers, cat capacity for hunger greater than did farmers and agriculture students, and cow and pig capacity for hunger greater than did citizens unrelated to agriculture. Farmers were comparable to specialized pig veterinarians, agriculture students, and citizens in their scores for hunger, pain, and fear, but gave higher boredom scores than citizens unrelated to agriculture. These results are consistent with evidence that stakeholders view animals differently based on their different values, norms, convictions, interests, and knowledge (Te Velde et al., 2002). For example, animal science students are known to hold strong values and interests regarding animal welfare (Heleski & Zanella, 2006) and learn about animal suffering during their course. Capacity to suffer is emphasized as the basis of moral concern for animals and belief in animal sentience is a strong predictor of attitudes towards animals and their use (Knight et al., 2009; Knight, Vrij, Cherryman, & Nunkoosing, 2004). Therefore, the widespread belief in animals' capacity to suffer expressed by our comparison groups is positive, particularly as the student populations are likely to work with animals in either agricultural or scientific contexts in the future, whilst farmers and veterinarians are currently responsible for the welfare of animals under their care.

Effects of Species on Perceptions of Animals' Capacity to Suffer

All species (dogs, cats, cows, and pigs) were judged to have the capacity to experience a range of negative sensations and emotions (hunger, pain, fear, and boredom). This is consistent with a survey of 200 members of the public which revealed widespread belief in animal sentience across a variety of species (Morris et al., 2012). Nevertheless, our study detected some important differences in the attribution of pain, fear, and boredom between species, with dogs receiving the highest scores. There were no differences between species in the attribution of hunger (unless controlling for the effect of occupation, see section above titled "Test of hypotheses"). Specifically, dogs were believed to be able to experience pain more than cows and pigs; fear more than cats and cows; and boredom more than cats, cows, and pigs. This is consistent with a survey of 425 students which found that dogs are perceived as highly sentient, exceeding new born babies, followed by foxes, pigs, chickens, rats, and fish (Phillips & McCulloch, 2005). In the current study, pigs were judged as comparable to dogs, cats, and cows in their capacity to feel fear. They were comparable to cats and cows in their capacity to feel pain, and comparable to cats, but more capable than cows, of feeling boredom. The attribution of human-like experiences and cognitive abilities to animals is known to be influenced by the degree of attachment to that species, with food animals attributed diminished capacity to suffer (Bastian et al., 2012; Bratanova et al., 2011; Eddy, Gallup, & Povinelli, 1993; Loughnan et al., 2010; Wilkins et al., 2015). It is therefore somewhat surprising that pigs were consistently judged to have similar emotional capabilities to cats, and they were judged more capable of feeling boredom than cows. Furthermore, citizens unrelated to agriculture judged pigs as comparable to cats and dogs, and more capable than cows, of experiencing hunger.

Davis and Cheeke (1998) carried out a survey of university staff and students in the US and found that non-food animals were judged to be more intelligent than livestock species, with the interesting exception of pigs who were judged to be comparable in intelligence to cats and dogs. The authors suggest that this could be due to the depiction of pigs in popular books and television programs as highly intelligent in comparison with other species produced for food (this has also been noted elsewhere: Arnold, 1988). Furthermore, a survey of animal

science students found that pigs were judged as more capable of experiencing pain and boredom than cows (Heleski & Zanella, 2006). Therefore, the current study contributes to the evidence that pigs are a livestock species perceived to hold strong mental capacities, and indeed this is supported by studies of pig cognition (Mendl, Held, & Byrne, 2010).

Effects of Age, Gender, and Location on Perceptions of Animals' Capacity to Suffer

There were some important demographic differences between our comparison groups. For example, pig farmers were predominantly male and on average exceeded 40 years of age, whilst animal science students were predominantly female and on average younger than 25 years old. These demographic differences were unavoidable in order to maintain the representativeness of each population. We controlled for demographic factors in our statistical models and the results confirmed that it was crucial to do so. Female participants judged animal capacity to experience pain and boredom to be greater than did males. This is consistent with previous research employing the same questionnaire which found that female veterinary students regarded cats and cows as more likely to feel pain than did male students (Paul & Podberscek, 2000). Furthermore, there is consistent evidence that, on average, females show higher levels of positive behaviors and attitudes toward animals; for example, by expressing greater empathy for animals (Colombo, Crippa, Calderari, & Prato-Previde, 2017; Hills, 1993), showing more opposition to animal use, and having greater involvement in animal protection activities (Heleski, Mertig, & Zanella, 2006; Herzog, 2007). Furthermore, we found weak negative correlations which revealed that older participants expressed less belief in animals' capacity to experience hunger and boredom than did younger participants. This is inconsistent with a survey of 96 members of the UK public which found that older participants had greater belief in the mental capacities of animals (Knight et al., 2004). The study, though, used different terms, and subsequent research indicates that younger people are most concerned about animal welfare (Vanhonacker, Verbeke, Van Poucke, & Tuytens, 2007). Participants in Ireland reported higher pain scores than did those in England and Scotland, although our sample size from the Republic of Ireland was smaller than that from Scotland and England. This implies that there may be cultural differences in perceptions of animal pain. This warrants further investigation.

Study Limitations and Directions for Future Research

There are several limitations to the current study which are important to highlight. Regarding the participants sampled, the student populations were limited to one institution and therefore the results cannot be generalized to student populations elsewhere. None of our respondents were based in Northern Ireland or Wales; therefore, our sample cannot be considered fully representative of the UK population. Furthermore, the sample of specialized pig veterinarians was small owing to difficulties in reaching this specialized demographic; this could have increased the risk of Type II errors, owing to a lack of statistical power. It is also possible that participants were influenced by experimenter effects whereby they responded in a way that they thought was desired rather than how they actually felt. Nevertheless, we did attempt to control for this bias by ensuring that all participants knew that their responses were confidential and could not be tied to any individual. Finally, a primary limitation of the current study was the restricted range of species, sensations, and emotions surveyed. A focus on a small number of species, and the emotions and sensations most likely to be directly elicited by common pig husbandry practices, was necessary to achieve a robust sample size.

The limited survey and study design employed here therefore provides only an initial exploration into this subject area. The extensive research into strategies employed by human omnivores to reduce cognitive dissonance provides several directions for future research. First, future research should build upon these findings by including a greater range of species and capacities, including higher-order traits, such as intelligence and secondary emotions, as employed in prior research into omnivores (Bastian et al., 2012; Bilewicz et al., 2011; Morris et al., 2012). Second, human omnivores display flexibility in their perceptions of animal sentience depending on recent behavior (Loughnan et al., 2010); this suggests that farmers' responses to the current survey may have been influenced by recent behavior. All farmers participated at farmer discussion groups rather than on the farm or whilst working with pigs. Repeating the current study whilst experimentally manipulating the timing of farmer participation (e.g., during painful husbandry tasks such as tail docking and tagging, at weaning, or at slaughter) may reveal that their perceptions of pig capacity to suffer change when being directly confronted with animal suffering. This could be developed further by including measures of farmer discomfort with such procedures as a potential mediator of any reductions in mind attribution. Third, human omnivores rationalize meat-eating by endorsing positive beliefs about meat that fit with their dietary practices. They defend eating meat as necessary (for health), natural, normal, and nice (the 4Ns: Piazza et al., 2015). People who endorse the 4Ns tend to attribute fewer mental capacities to cows, include fewer animals in their circle of moral concern, consumed more animal products, are not motivated by ethical concerns in their buying decisions, and experience less guilt about their animal-product decisions (Piazza et al., 2015). Piazza et al. (2015) concluded that the 4Ns are a powerful, pervasive tool employed by individuals to reduce cognitive dissonance, but to date the use of the 4Ns has never been investigated in farmers. Fourth, human omnivores adjust perceptions of personal responsibility by placing the blame with other stakeholders, such as retailers and the government (Bastian & Loughnan, 2017; Schröder & McEachern, 2004); some evidence suggests that farmers employ this strategy (Te Velde et al., 2002). This may be particularly relevant if farmers feel constrained in their ability to improve welfare owing to small profit margins. Finally, human omnivores emphasize "responsible" behavior; for example, by under-reporting how frequently they eat meat, limiting their meat intake, or only eating certain types of meat (Bastian & Loughnan, 2017; Rothgerber, 2014, 2015a, 2015b). It is possible that farmers employ an equivalent strategy by emphasizing responsible behavior on their farm. The strategy employed to reduce dissonance is likely to depend on a range of contextual factors, and when one fails another will take hold (Bastian & Loughnan, 2017).

Therefore, psychological defenses employed by omnivores to resolve dissonance have been widely researched and have important implications for animal consumption. However, no research has investigated how these additional psychological defenses are employed during the meat production process itself. Farmers are directly responsible for the welfare of their animals, and the psychological and behavioral strategies that they employ may have important implications for their motivation to improve animal welfare. This is therefore an important area of future research.

Conclusions

We found that pig farmers ascribed pigs with similar capacities to suffer as cows, dogs, and cats and showed similar outcomes to agriculture students, animal science students, pig veterinarians, and citizens unrelated to agriculture. This study provides the first investigation into

cognitive dissonance related to the “meat paradox” in farmers. Cognitive dissonance mechanisms might be at play in farmers and this might affect their incentives to improve farm animal welfare. This deserves further investigation.

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Conflicts of Interest

The authors declare no conflict of interest.

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5. Conclusions

Capacity to suffer is emphasised as the basis of moral concern for animals and belief in animal sentience is a strong predictor of attitudes towards animals and their use (Knight et al., 2004; Knight et al., 2009; Proctor, 2012). Therefore, farmers' perception of pig capacity to suffer has important implications for the treatment of their animals, and their willingness to reduce animal welfare issues such as aggression. Human belief in animal sentience is flexible and depends on species (pet versus livestock) and circumstances (e.g. recent consumption of meat); with human omnivores reducing their perceptions of animal capacity to suffer in order to reduce discomfort associated with meat-eating (Loughnan et al., 2010; Bilewicz et al., 2011; Bratanova et al., 2011; Bastian et al., 2012; Wilkins et al., 2015). A prediction borne from this psychological theory is that farmers will reduce their perception of pig capacity to suffer in order to reduce discomfort associated with the harmful impact of the production system on their animals. Nevertheless, this study provided evidence for widespread belief in pigs' capacity to suffer amongst pig farmers, as well as specialised pig veterinarians, animal science students, agricultural students, and citizens unrelated to agriculture. Therefore, the results of this study suggest that a lack of belief in pigs' capacity to suffer does not contribute to the non-

financial reasons behind farmers' reluctance to control pig aggression. Furthermore, the sensations / emotions of pain, hunger, fear and boredom which were surveyed here are relevant to many other challenges faced by intensively reared pigs. Therefore, the results of this study have implications not only for aggression, but also other stubborn pig welfare issues such tail biting (D'Eath et al., 2016) and docking (Wilson et al., 2014), lameness (KilBride et al., 2009), lack of opportunity to display innate behaviours (Taylor et al., 2010), and chronic hunger as a result of sows' feed-restricted diet (D'Eath et al., 2018). Therefore, farmers perceive pigs as capable of suffering, but it remains unclear whether farmers perceive aggression as a source of suffering. An important next step is to explore farmers' perceptions of aggression between pigs, and in particular whether they are efficient at recognising the occurrence and impact of the behaviour. This is explored in the following chapter.

Supplementary materials: The survey for farmers and non-farmers can be found in appendices A and B respectively.

Chapter 4: Farmer perceptions of pig aggression compared to animal-based measures of fight outcome

1. Introduction

In Chapter 3 I established that farmers perceive pigs as capable of suffering. However, it remains unclear whether farmers perceive aggression as a source of suffering for their animals. Farmers' willingness to alter their management practices to reduce aggression will be strongly determined by whether they are efficient at recognising the occurrence and impact of the behaviour. It is likely that farmers who recognise when a pig has been in a severe fight will be more likely to take action. Nevertheless, desensitization due to frequent exposure can threaten human ability to recognise and respond to suffering (e.g. Carnagey et al., 2007; Anderson et al., 2010; Greitemeyer and Mugge, 2014; Brockmyer, 2015). It is, therefore, possible that farmers are inefficient at recognising the impact of aggression on their animals, and that this may be mediated by frequent exposure. The purpose of this chapter is to establish the extent to which farmers recognise and differentiate severities of aggression and whether this is influenced by their experience of working with pigs. Farmers' perceptions of pig fights and their outcomes observed in video clips were compared to objective measures of exhaustion (blood lactate) and injury (skin lesions) taken from the animals. Skin lesions as a

result of receiving bites (i.e. bite marks) are a good indicator of the severity of aggression (Turner et al., 2006) and have been used as a validated proxy measure of aggressive behaviour (Turner et al., 2006; Desire et al., 2015; Turner et al., 2018). Blood lactate gives a quantified, physiological measure of fatigue, and has been advocated as a measure of contest cost (Prenter et al., 2006; Camerlink et al., 2015). Furthermore, blood lactate is positively correlated with the traditional measure of contest cost, namely contest duration (Camerlink et al., 2015; McGinley et al., 2015). Pig blood is comparable to that of humans (Weng and Cloutier, 1996; Marascalco et al., 2006), and some of the pigs observed in the current study displayed extreme values which were comparable to intense peak performances in human sport competitions (Billat, 1996; Camerlink et al., 2015); therefore, suggesting that some of these aggressive interactions were extremely energetically demanding. Finally, farmers' perceptions were compared to those of participants with experience of working with pigs but in a different capacity (specialist pig veterinarians), and without experience (agricultural students and animal science students). This chapter consists of a published research article (Section 2) and concluding remarks (Section 3).

2. Journal article

Declaration

Rachel Peden designed this study, collected data, analysed data and wrote the original version of the manuscript. Simon Turner and Laura Boyle helped to collect data at farmer discussion groups. Simon Turner provided advice on appropriate statistical analysis. Simon Turner, Faical Akaichi, Irene Camerlink and Laura Boyle provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to external peer review comments and prepared the response letter for the journal and was the corresponding author. Inclusion of this publication complies with copyright laws. Permission from co-authors was obtained regarding the inclusion of this article in the current thesis.

Article

Farmer Perceptions of Pig Aggression Compared to Animal-Based Measures of Fight Outcome

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Simple Summary: Aggression between pigs is a major animal welfare issue in commercial farming, however only a minority of farmers believe that aggression is a problem that needs to be addressed. We investigated whether the farmers' reluctance to reduce aggression is linked to desensitization as a result of their frequent exposure to the behavior. We showed farmers video clips of pigs during and immediately after a fight and they judged through a questionnaire the severity of what they saw. These judgments were compared to (a) animal-based measures of injury (skin lesions) and exhaustion (blood lactate), and (b) human observers with and without experience of working with pigs. Farmers perceived fights as severe and were motivated to prevent them continuing. They were not desensitized to aggression as their judgments were similar to those of participants who had never worked with pigs. When farmers (and comparison groups) did not see the fight occurring, they judged exhaustion and injuries to be lower than indicated by the animal-based measures. Farmers could benefit from information on how to better assess the impact of aggression by scoring lesions and from evidence of the economic and welfare impact of these lesions.

Abstract: Several animal welfare issues persist in practice despite extensive research which has been linked to the unwillingness of stakeholders to make changes. For example, most farmers do not perceive pig aggression to be a problem that requires action despite the fact that stress and injuries are common, and that several solutions exist. Frequent exposure to animal suffering could affect farmer responses to distressed animals. This study investigated for the first time whether this occurs, using pig aggression as a focus. Using video clips, 90 pig farmers judged the severity of aggression, level of pig exhaustion and the strength of their own emotional response. Their judgments were compared to objective measures of severity (pigs' skin lesions and blood lactate), and against control groups with similar pig experience (10 pig veterinarians) and without experience (26 agricultural students; 24 animal science students). Farmers did not show desensitization to aggression. However, all groups underestimated the outcome of aggression when they did not see the fight occurring as compared to witnessing a fight in progress. We suggest that farmers be provided with evidence of the economic and welfare impact of aggression as indicated by lesions and that they be advised to score lesions on affected animals.

Keywords: aggression; animal welfare; desensitization; perception; pigs

1. Introduction

Farmers are frequently exposed to a range of animal welfare issues, yet they are often unwilling to implement recommendations to improve animal welfare [1–3]. It is known that frequently witnessing human suffering can disrupt human emotional, cognitive and behavioral responses to witnessing distress [4,5]. The current study investigates for the first time whether exposure to animal suffering disrupts farmer responses to animal suffering, using pig aggression as a case study.

Desensitization is a well-established defense mechanism which occurs automatically and unconsciously [4,5]. For example, regular exposure to violence can lead to a reduced emotional response to violence [6], reduced empathy for the victims of violence [4] and increased violent behavior [7]. When witnessing human suffering, the decision to intervene is determined firstly by perceiving there to be an urgent problem that needs to be addressed, followed by feeling personal responsibility to act [8]. Desensitization can interfere with this decision-making process by making incidents less likely to be noticed, by reducing the perceived seriousness of the suffering and by reducing feelings of personal responsibility [6]. It has previously been noted that agricultural communities may become desensitized to animal suffering as they are exposed to it on a regular basis [5]. However, this hypothesis has never been empirically studied despite potentially having important implications for animal welfare and farm efficiency.

Pig aggression is common in commercial farming as pigs fight to establish dominance relationships following regrouping [9]. In the UK and Ireland, growing pigs are typically regrouped at least once per production cycle, but this can reach as many as four times [10,11], whilst sows are returned to group housing during each gestation [12]. Regrouping occurs to optimize the use of space and to maintain homogeneity in groups (e.g., similar body weight or same gestational phase). Therefore, most farmers regroup animals regularly, and the exact frequency depends on the management of pig batches and farm size. As a result, intensive pig farmers will frequently witness animal suffering due to aggression during their working lives. Aggression between pigs often results in stress for the animals, which can compromise their growth performance [13–15], reproductive success [16–18] and immune competence [19,20], whilst injuries can impact upon carcass quality [21,22]. However, a recent survey of 167 UK pig farmers revealed that the majority of farmers did not perceive aggression between unfamiliar pigs to be a problem that needs to be addressed [10]. Furthermore, only a minority of farmers attempt to control aggression when regrouping, despite the existence of several effective aggression mitigation strategies [23,24]. These strategies require farmers to make specific changes to animal management or nutrition. For example, allowing litters to mix prior to weaning, housing pigs in large social groups, and enhancing levels of tryptophan in the feed can all reduce the occurrence or intensity of aggression at regrouping [23,25]. It is, therefore, possible that farmers underestimate the impact that aggression has on the welfare and productivity of their animals. The current study aims to investigate: (1) whether farmers underestimate the physical impact of pig aggression and; (2) if this response is influenced by the amount of experience of working with pigs.

2. Materials and Methods

2.1. Overview

We asked 90 farmers for their perceptual and emotional response to six video clips of aggressive encounters between pigs, employing a paper-based survey. Control groups of non-farmers with experience of working with pigs (10 pig veterinarians) and without experience of working with pigs (26 agricultural students and 24 animal science students) completed an amended version of the survey. Farmers' scores were compared against the scores of the comparison groups and against objective measures of severity (relative change in number of skin lesions and blood lactate as a result of the interaction) in order to investigate whether farmers underestimate the physical impact of aggression on pig welfare, and how the amount of experience of working with pigs may influence perceptions.

2.2. Ethical Approval

All animal experimentation was approved by Scotland's Rural College's (SRUCs) Animal Ethics Committee and the U.K. Government Home Office, ensuring compliance with EC Directive 86/609/EEC for animal experiments. This study was conducted in accordance with the Declaration of Helsinki. This study received internal ethical approval from the Human Ethical Review Committee at the University of Edinburgh (Project identification code: HERC_88_17), and informed consent was obtained for all participants.

2.3. Selection of Video Clips

Video footage was obtained from a separate research project carried out in 2015 at Scotland's Rural College (SRUC) whereby 168 growing pigs were video recorded in dyadic encounters comprising aggressive interactions. For each pig, measures of skin lesions and blood lactate were taken pre- and post-encounter to indicate relative change as a result of aggression. Skin lesions as a result of receiving bites (i.e., bite marks) are a good indicator of the severity of aggression [21]. Skin lesion count is a validated proxy measure for aggression that is moderately heritable and has been applied in animal welfare assessments [21,26]. Blood lactate gives a measure of physical fatigue. Further details of the dyadic encounters, lesion recording and lactate measurements are provided in [27].

A stepwise selection process was adopted to identify six video clips to be shown to observers. First, pigs that displayed a negative relative change in blood lactate, and therefore displayed a reduction in blood lactate following the fight, were eliminated from the dataset ($n = 26$, see Table 1 for descriptive statistics of the remaining dataset). Second, based on the severity of skin lesions and blood lactate, we identified from the remaining dataset the encounters in which both pigs obtained high (upper quartile, UQ), medium (interquartile range, IQR) or low (lower quartile, LQ) severity measures. Video clip 1 displayed a medium severity mutual fight and was always seen first. This 'dummy' clip acted as a practice and a common start point. Moreover, by displaying a typical aggressive encounter, this clip sets the scene for the following experimental clips. Clips 2–4 displayed pigs of low, medium and high severity encounters immediately after the fight ended. Videos of pigs with lesions and lactate in the IQR were also selected showing behavior during the actual occurrence of a fight or during bullying (winner chases the loser) to account for the different types of aggression seen on farms (clips 5–6). This ensured that all observers viewed fights that had ended and interactions that were in progress. The severity and content of each 20 s video clip can be seen in Table 2. Participants were asked to focus on one specific pig. The focal pig obtained severity measures which were as similar as possible to those of the non-focal pig. For exact measures of lesion score and blood lactate for both the focal and non-focal pigs, see Table 3. For a detailed description of the stepwise selection process and criteria, see Appendix A.

Table 1. Descriptive statistics regarding measures of relative change in lesions (number of lesions per pig) and blood lactate (mmol/L) following the fight, compared to before the fight, for the dataset ($n = 142$).

Measure	Blood Lactate	Lesion Score
Mean	7.76	57.37
Min	0	0
Quartile 1	2.15	12.75
Quartile 2	42.00	5.85
Quartile 3	13.20	77.25
Max	21.20	354

Table 2. Severity and content of each 20 s video clip displaying an aggressive encounter between two pigs. (LQ = lower quartile; IQR = interquartile range; UQ = upper quartile).

Clip	Blood Lactate	Lesion Score	Behavior
1 ('Dummy')	IQR	IQR	During mutual fight
2 ('Fight outcome: Low')	LQ	LQ	After fight
3 ('Fight outcome: Medium')	IQR	IQR	After fight
4 ('Fight outcome: High')	UQ	UQ	After fight
5 ('During fight: Mutual')	IQR	IQR	During mutual fight
6 ('During fight: Bullying')	IQR	IQR	During bullying

Table 3. Exact measures of relative change in lesion score (number of lesions per pig) and blood lactate (mmol/L) following the fight, compared to before the fight, for the pigs in each video clip.

Clip	Focal Pig		Non-Focal Pig	
	Blood Lactate	Lesion Score	Blood Lactate	Lesion Score
1	3.4	20	5.1	31
2	0.6	2	0.3	0
3	4.3	55	8.8	30
4	20.8	82	16.8	94
5	9.4	56	5.8	24
6	5	45	12	0

The order effects across the observation sessions were controlled for by creating six clip orders, as outlined in Table 4. Footage was edited using Windows Movie Maker (version 2012) and each clip was selected to be 20 s long and such that the focal pig was clearly identifiable. The clips were selected towards the end of the aggressive encounter (clips 1, 5 and 6) or immediately after (clips 2, 3 4), such that the behavior performed was as closely matched in time to the measures of lesions and lactate as possible. Images were played back with sound during observer scoring sessions. Before the clip began, a 'freeze-frame' showed the focal pig circled alongside a message stating '*please focus on this pig*'. Furthermore, during the clip, every time the focal pig made a major change to its position an arrow appeared pointing towards it.

Table 4. Each of the six clip orders.

Block	Clip Order					
	A	B	C	D	E	F
1	1	1	1	1	1	1
2	3	4	2	3	4	2
2	4	2	3	4	2	3
2	2	3	4	2	3	4
3	5	5	5	6	6	6
3	6	6	6	5	5	5

2.4. Survey Design

Answer sheets contained two main sections. Section 1 entitled 'demographics' collected information on the farmer's age (year of birth), gender, role on the farm, farm size and years of experience working with pigs. Farmers were also asked: 'Do you ever intervene during aggressive encounters between pigs on your farm? (Please tick ALL statements that you agree with from: No, there is no point; No, I never see aggressive encounters on my farm; No, it is too dangerous; Yes, when profitability is likely to be affected, and; Yes, to reduce injuries/stress for the animals)'. Section 2, entitled 'videos', was completed alongside watching the assigned movie. Following each video clip, the movie was paused and farmers were asked to place a downward line through three separate

100 mm visual analogue scales (VAS) at a point they felt best represented: (i) how much of a negative emotional reaction they had, from no negative reaction to strongest possible negative reaction; (ii) how exhausting they believed the fight was for the focal pig, from not exhausting at all to the most exhausting possible; (iii) how severe they believed the fight was for the focal pig, from not severe at all to the most severe seen on farms. Additionally, participants were asked what factors they used to judge the severity of the fight ('Tick all relevant factors from: number/severity of skin lesions, vocalizations, panting, other sounds (e.g., banging), facial expression, stress and others'). For clips 1, 5 and 6 (during fights), farmers were also asked; (iv) if they saw this fight on their farm, how much they would want to prevent it continuing, from not at all to the most possible. Sections 1 and 2 were amended slightly for non-farmers by removing all farm-related questions and replacing them with those relevant to the control group. For example, questions regarding their role on the farm and farm size were excluded and participants were alternatively asked about their occupation. Participants were instructed not to talk to each other in order to avoid possible effects of their discussions on their answers. For farmer and non-farmer response sheets, see Supplementary Materials.

2.5. Recruitment

Participants were recruited between February 2017 and November 2017. Ninety pig farmers were recruited whilst participating in six discussion group events held in the UK and Ireland, organized by Scotland's Rural College ($n = 26$), Teagasc ($n = 29$) and the Agricultural and Horticultural Development Board (AHDB) Pork ($n = 35$). Ten specialized pig veterinarians participated at the same discussion groups. Veterinarians provide an interesting comparison group due to their comparable years of experience working in the pig industry as the farmers. Farmers and veterinarians were unaware that they would be asked to participate in a study on pig aggression prior to attending the discussion groups. Sixty-one students participated in twelve groups following lectures at SRUC; 35 were students of Agriculture, and 26 studied Animal Science. The student populations provide interesting comparison groups due to their knowledge of farming and livestock, but lack of experience working directly with pigs. Students were unaware that they would be asked to participate in a study on pig aggression prior to attending the lectures. The order of presentation of video clips in Table 4 was replicated twice for students since there were 12 groups compared to the 6 groups of farmers and veterinarians. All responses were collected through 'face to face' recruitment; this does not allow response rate calculations. Furthermore, we had no control over the composition of the groups with respect to occupation, so it was not possible to balance each clip order to have the same number of people from each occupation (Table 5).

Table 5. Total number of participants who watched each of the six clip orders.

Clip Order	Total N			
	Farmers	Pig Veterinarians	Agricultural Students	Animal Science Students
A	26	4	6	0
B	9	0	1	8
C	7	1	6	2
D	20	0	4	6
E	20	3	1	2
F	8	2	8	6
Total	90	10	26	24

2.6. Demographics of the Final Sample

Nine agricultural students and two animal science students were excluded from the analysis due to reporting prior experience of working with pigs. In total, 150 participants with the following demographics were included:

(1) Pig farmers ($n = 90$) were mostly male (93.3%; female: 6.7%) and were on average 41.5 years old (s.d. = 14.13, range = 17–81 years) with 19.53 years of experience working with pigs (s.d. = 14.74, range = 0.5–65 years). There was a strong, positive correlation between years of experience and age ($r = 0.871$, $p < 0.0001$). Therefore, only age was included in the statistical analysis but it was considered informative of both age and experience effects. Farmers were mainly farm workers (41.1%), owners (32.2%) and managers (17.8%). The remaining farmers were contract farmers (6.7%) and retired (2.2%). A total of 28.9% were based in Scotland, 38.9% were based in England and 32.2% in Ireland. Additionally, 86.7% of farmers reported currently keeping sows, whilst 67.8% kept weaners (i.e., recently weaned piglets), 55.6% kept growers and 62.6% kept finishers. Therefore, most farmers kept pigs at more than one stage of production. The mean number of pigs kept at each stage of production can be found in Table 6.

(2) Specialized pig veterinarians ($n = 10$) were mostly female (70%; male: 30%) and were on average 40.6 years old (s.d. = 14.4, range = 24–64 years) with 15.3 years of experience working with pigs (s.d. = 17.6, range = 0.75–40 years). Of this group, 40% were based in Scotland and 60% were based in England.

(3) Agricultural students ($n = 26$; 46.2% male, 53.8% female; mean age = 21.4 years, s.d. = 1.65, range = 20–28) were in their 3rd ($n = 23$) and 4th ($n = 3$) years of study.

(4) Animal science students ($n = 24$; 16.7% male, 83.3% female; mean age = 22.2 years, s.d. = 2.97, range = 20–35) were in their 3rd ($n = 15$) and 4th ($n = 8$) years of study. All students were based in Scotland.

Table 6. Mean number of pigs kept at each stage of production at any one time (in brackets are the number of farmers that kept pigs at the specified stage of production), range and standard deviation (s.d.).

	Mean (Number)	Range	s.d.
Weaners	1929 (61)	150–10,000	1829.12
Growers	2850 (50)	10–30,000	5787.05
Finishers	3835 (56)	100–38,000	7109.85
Sows	1100 (78)	40–13,500	2127.45

2.7. Statistical Analysis

Statistical analyses were conducted in Statistical Package for the Social Sciences (SPSS, version 25, International Business Machines Corp., Armonk, NY, USA). Normality of the data was assessed by inspection of the residuals and data were transformed wherever necessary. Residual maximal likelihood (REML) models were run to investigate the factors that influence: (1) Emotional response; (2) Judgment of fight severity; (3) Judgment of exhaustion; and (4) Motivation to intervene if the interaction had occurred on their own farm. The fixed effects in the first three models were gender, age, occupation and the video clip. Occupation was not included as a fixed effect in the fourth model as only farmers were asked the question ‘If you saw this fight on your farm, how much would you want to prevent it continuing?’. The clip order was included in each model as a random effect. The main effects were removed if $p > 0.1$ and the model was re-run until the simplest model was achieved. Post hoc analyses were conducted using least significant difference (LSD) tests with a Bonferroni correction made for multiple comparisons. Six Chi Square tests were carried out to ascertain the effects of occupation on the cues used to judge fight severity. The dependent variables were the use of: (1) lesions; (2) vocalizations; (3) panting; (4) other sounds (e.g., banging); (5) facial expression and; (6) stress when judging fight severity. The results were considered statistically significant where $p < 0.05$.

3. Results

A total of 78.9% of farmers indicated that they do intervene when they see pigs fighting on their own farm; 13.3% indicated that they did so when profitability was likely to be affected and 76.7% did so to avoid injuries/stress for the animals. Furthermore, 15.6% of farmers reported that they did not

intervene during aggressive encounters on their farm; 7.8% believed there was no point, 2.2% never see aggressive encounters on their farm and 5.6% believed it is too dangerous.

The clip order had no effect on emotional response, judgment of severity, judgment of exhaustion or motivation to intervene. The results of all the main effects are described below.

3.1. Main Effects of Occupation

There were significant main effects of occupation on emotional response and judgment of exhaustion across video clips (Table 7). Pairwise comparisons revealed that farmers and animal science students expressed greater emotional response scores when compared to agricultural students ($p < 0.05$; Figure 1a). Farmers judged fight exhaustion to be higher than agricultural students ($p < 0.01$; Figure 1b). Occupations did not differ in their judgments of severity ($p > 0.05$) (Figure 1c). Participants employed a range of cues when judging severity (see Figure 2). There was no effect of occupation on use of skin lesions, vocalizations, panting, facial expressions or stress when judging the severity of aggressive encounters ($p > 0.05$). However, there was an effect of occupation on use of ‘other sounds (e.g., banging)’ ($p < 0.01$), with animal science students using this cue significantly more than farmers and agricultural students ($p < 0.05$).

Table 7. The results of four residual maximal likelihood (REML) models investigating the factors that influence: (1) emotional response; (2) judgment of exhaustion; (3) judgment of severity and; (4) motivation to intervene. The main effects were removed from the model if $p > 0.1$ unless involved in a significant interaction.

Main Effect	F (df)	<i>p</i>
Emotional response		
Gender	7.0 (1)	0.009
Occupation	4.5 (3)	0.004
Video clip	136.4 (4)	0.001
Judgment of exhaustion		
Gender	8.4 (1)	0.004
Occupation	4.8 (3)	0.002
Video clip	131.6 (4)	0.001
Judgment of severity		
Gender	6.8 (1)	0.010
Age	8.1 (1)	0.005
Video clip	153.6 (4)	0.001
Farmer motivation to intervene		
Gender	4.9 (1)	0.029
Age	4.9 (1)	0.030
Video clip	8.7 (1)	0.004

3.2. Main Effects of Video Clip

There were significant main effects of video clip on emotional response, exhaustion score, severity score and farmer motivation to intervene across occupations (Table 7). The mean emotional response, exhaustion score and severity score for the low severity outcome clip (lower quartile lactate and lesions) showing pigs after a fight (clip 2) were significantly lower than for the medium and high severity outcome clips (clips 3 and 4), as well as for the mutual fight and the bullying clips (clips 5 and 6; $p < 0.01$). Emotional response and severity scores for the medium and high severity outcome clips showing pigs after a fight (clips 3 and 4) did not differ ($p > 0.05$) but the exhaustion scores did ($p < 0.001$), whereby pigs with a higher lactate level and more lesions were regarded as being more exhausted. Emotional response, exhaustion score and severity score for both of the ‘during fight’ clips (clips 5 and 6) were greater than the scores for the ‘post-fight’ clips, and responses to the bullying clip

(clip 6) were significantly greater than to the mutual fight clip (clip 5) ($p < 0.001$; Figure 3a–c). Farmer motivation to intervene was significantly greater for the bullying clip than for the mutual fighting clip (Bullying: mean = 79.4, SE = 2.4; Mutual fight: mean = 72.0, SE = 2.5; $p < 0.01$).

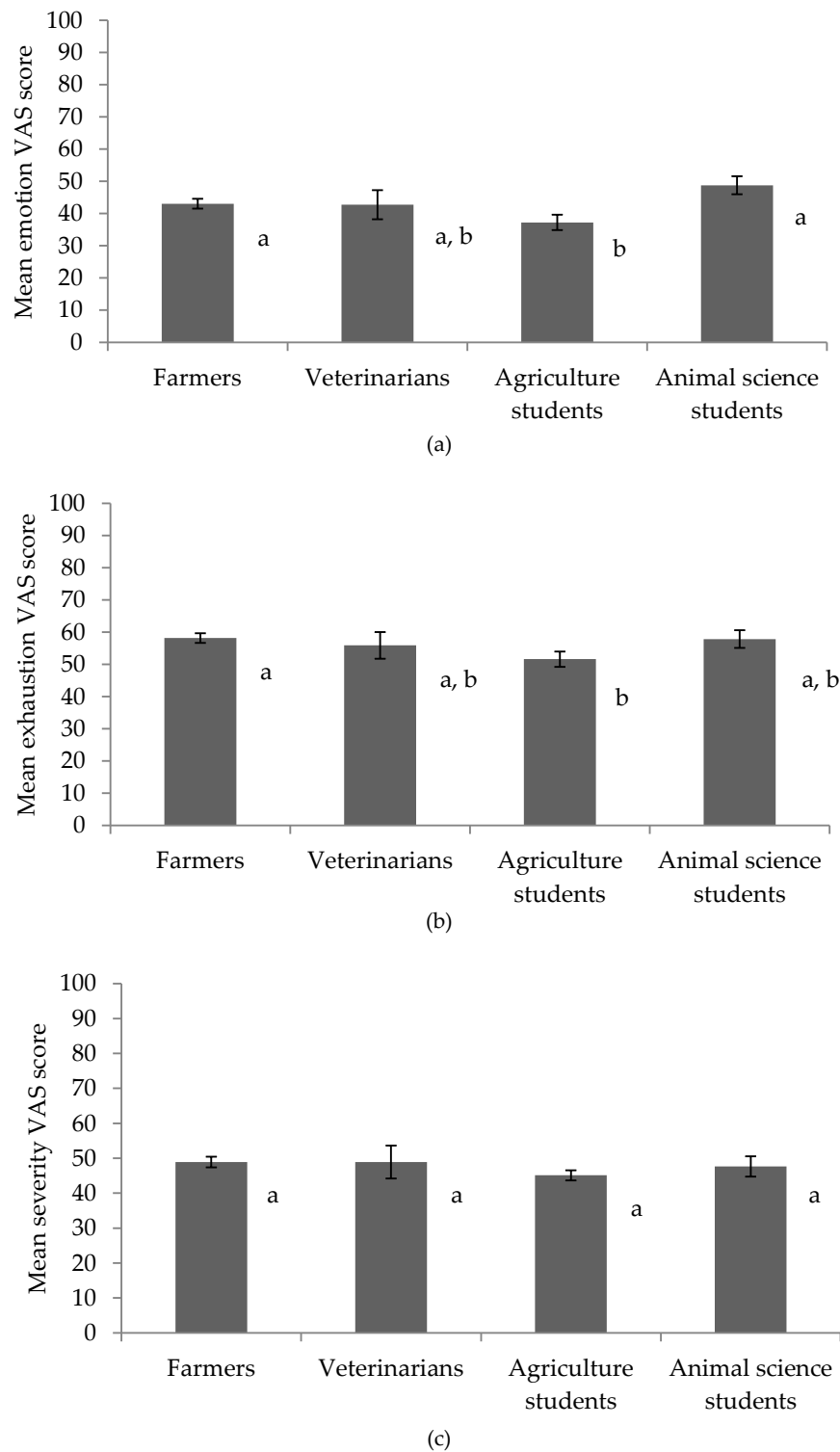


Figure 1. Mean visual analogue scale (VAS) scores for (a) emotion, (b) exhaustion, and (c) severity according to occupation; whereby occupations with different letters express a significant difference in mean response.

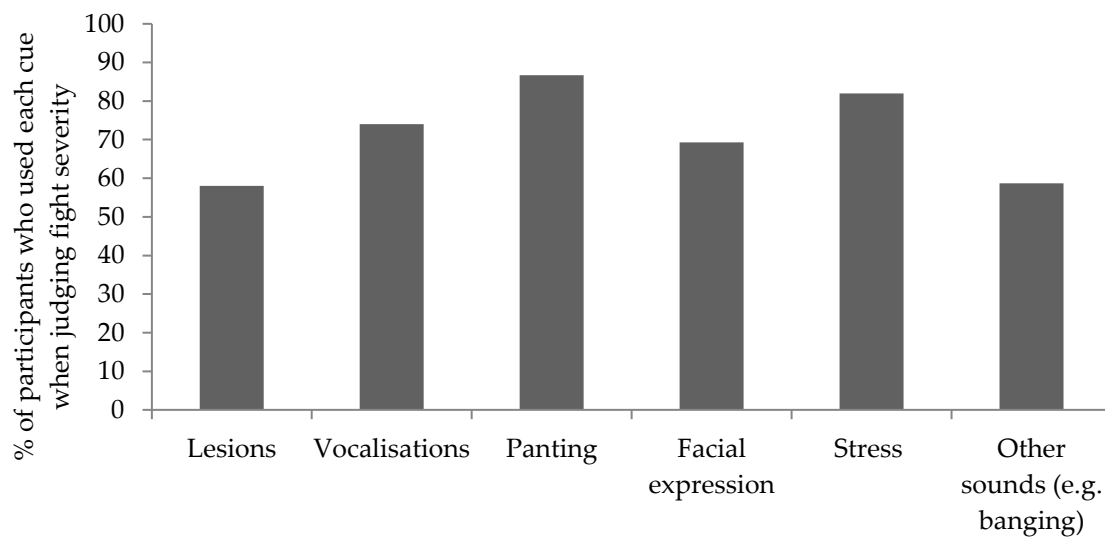


Figure 2. Percentage of participants who used each cue when judging fight severity.

3.3. Demographic Effects

Across occupations, women expressed significantly greater VAS scores compared to men for emotional response (Females: mean = 46.1, SE = 2.0; Males: mean = 41.6, SE = 1.4; $p < 0.01$), judgment of exhaustion (Females: mean = 59.2, SE = 1.9; Males: mean = 55.9, SE = 1.4; $p < 0.01$), and judgment of severity (Females: mean = 50.0, SE = 2.0; Males: mean = 47.2, SE = 1.4; $p < 0.05$). Female farmers also expressed greater motivation to intervene than male farmers (Females: mean = 88.8, SE = 3.5; Males: mean = 74.8, SE = 1.8; $p < 0.05$). There was a significant effect of age on farmer motivation to intervene ($p < 0.05$) with older farmers expressing greater motivation to intervene, although the significant positive correlation was weak ($r = 0.148$, $p < 0.05$). There was a significant effect of age on judgment of severity ($p < 0.01$) most likely linked to a cohort of young participants (agriculture students) who gave lower scores.

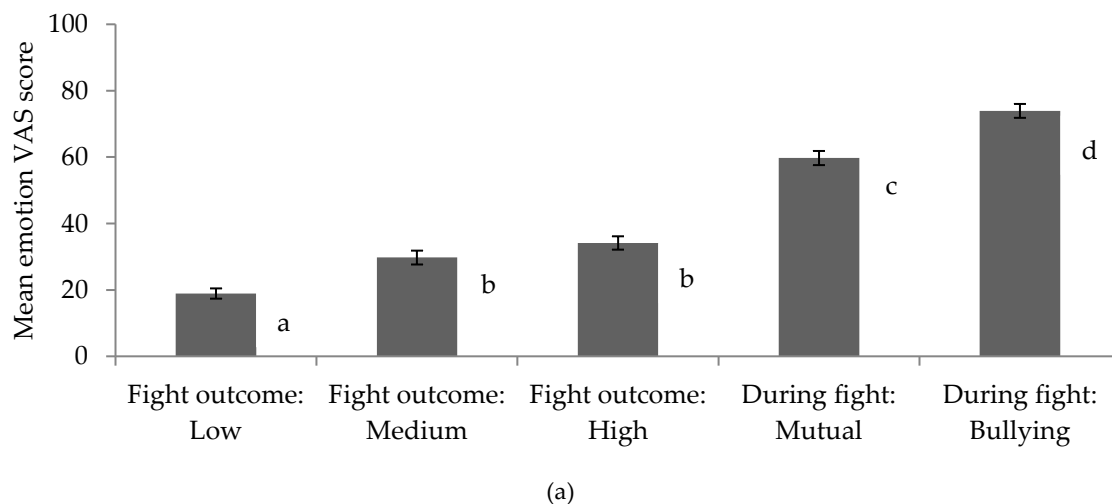


Figure 3. Cont.

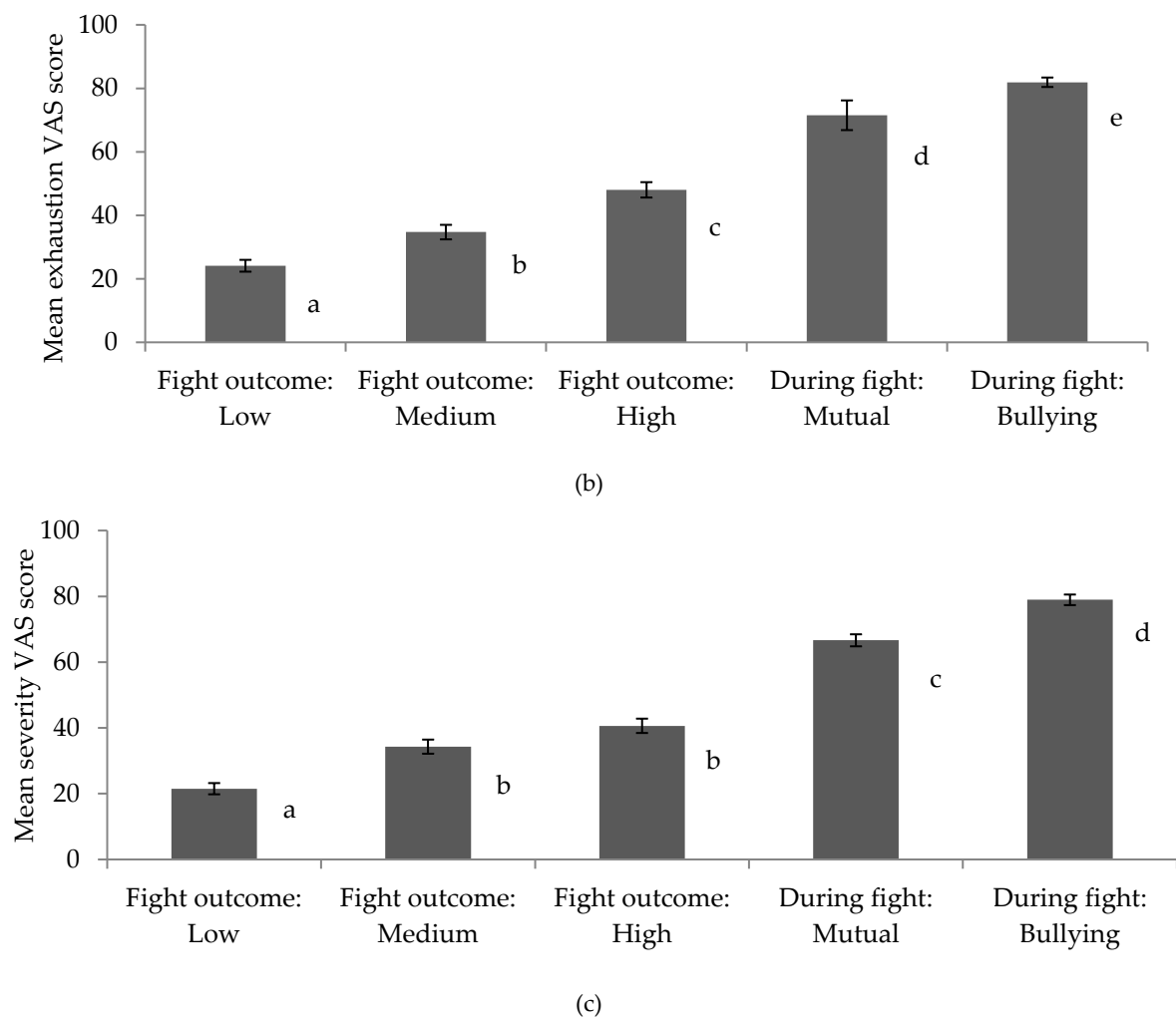


Figure 3. Mean visual analogue scale (VAS) score for (a) emotion, (b) exhaustion, and (c) severity according to video clip; whereby video clips with different letters express a significant difference in mean response.

4. Discussion

It is known that frequent exposure to suffering can disrupt human emotional, cognitive and behavioral responses to signs of distress [4,5], and the current study provides the first investigation into whether or not routine exposure to animal suffering disrupts farmer responses, using pig aggression as a case study. Our survey amongst 90 farmers and 60 control participants showed that farmers are not desensitized and in fact are motivated to change the situation when noticed. All participants assessed aggression as severe when having seen the fight, but underestimated the impact of aggression when the animals were viewed immediately after the fight had ended (assessed through objective animal-based measures).

4.1. Perceptions of Aggression

All comparison groups judged aggressive behavior in-action to be highly severe and exhausting for the animals, and experienced a negative emotional response to these interactions. Responses were particularly high for bullying aggression in comparison to mutual aggression, despite both encounters resulting in medium severity measures of blood lactate and skin lesions. Farmers reported that, if they saw these interactions on their farm, they would be highly motivated to prevent them continuing. Indeed, the majority of farmers reported that they do intervene when they see aggressive interactions

on their farm, and their primary motivation for doing so was to reduce injuries and stress for the animals. Nevertheless, all comparison groups underestimated the impact of aggression as indicated by skin lesions and blood lactate when they did not see the fight occurring. Specifically, the perceived seriousness of injuries and exhaustion as a result of aggression, as well as judgments of their own emotional response, were lower when observing the animals immediately after a fight had ended, even when the outcomes were severe as indicated by objective measures. Furthermore, judgments of severity and emotional response did not differ between the medium and high severity post-fight outcome clips, suggesting that the participants perceived little difference between these outcomes.

Farmers are often engaged in a wide range of tasks performed in different buildings which makes it difficult for them to witness post-mixing fights as frequently as they actually occur. Farmers are expected to witness the injuries from such interactions during their regular animal inspections. However, results suggest that farmers are unlikely to fully recognize the severity of these outcomes and this may contribute to the limited uptake of recommendations from aggression research in commercial practice.

Farmers were not desensitized to aggression as a result of frequent exposure to the behavior; farmer perceptions of fight severity were comparable to those of participants with, and without, experience of working with pigs, and all participants employed a range of pig-based cues (lesions, facial expression, panting, stress and vocalizations) to a similar extent when making these judgments. Farmers and agriculture students did use 'other sounds (e.g., banging)' less than applied animal science students, which suggests that they relied on a more limited set of cues when making their judgments. However, it is unclear why this occurred. Farmers judged exhaustion to be significantly higher than agricultural students. Furthermore, farmers and applied animal science students experienced a greater negative emotional response to aggression when compared to agricultural students. Stakeholders differ in their knowledge, interests, values and norms regarding livestock. This can influence their perceptions of animal welfare [28–30] and may have contributed to the lower responses detected for agricultural students.

There were important differences between our comparison groups in their age and gender, and results confirmed that it was crucial to control for these differences in statistical analysis. Women on average gave higher scores than men for emotional response, judgment of severity and judgment of exhaustion, and female farmers were more motivated to intervene during fights than male farmers. This is consistent with evidence that, on average, females show more positive behaviors and attitudes toward animals; for example, by expressing greater empathy for animals [31,32], more opposition to animal use, and greater involvement with animal protection activities [33,34]. Furthermore, older farmers expressed greater motivation to intervene than younger farmers. Therefore, as age and years of experience were highly related, farmer experience may actually enhance their responses to fights. Age also influenced participant judgments of severity, which was determined by a subgroup of young participants who gave lower scores (agriculture students).

4.2. Animal Welfare Implications

The results indicate two important targets for implementing a change in practice. Firstly, farmers must be made aware of how to accurately determine the physical impact of aggression when they have not witnessed the fighting behavior. One useful tool for farmers to achieve this is scoring or estimating the number of visible lesions on affected animals. Counting lesions, or the simplified skin lesion score method, is an established and accurate measure of aggressive behavior which is regularly employed in research [21,35]. Secondly, researchers should calculate the economic and welfare impact of aggression as indicated by the lesions. If farmers observe the true frequency and intensity of fighting behavior on their own farm, and understand its impact on farm productivity, their motivation to control the issue is likely to increase. This advice regarding the recognition of aggression as a problem should be translated effectively to farmers and other stakeholders within the industry. Veterinarians

are particularly important as they are the most valued source of information to farmers and highly influential in determining their animal welfare decisions [11,36].

4.3. Evaluation of Novel Methodology

The current study employed a novel methodology whereby perceptions of aggression exhibited in video clips were compared to objective, physiological measures of the severity of the welfare threat. There are many other animal welfare issues that have been resistant to change despite extensive research [3,37,38]. This novel methodology may represent a useful tool to assist in establishing stakeholder perceptions of these issues, in order to tailor successful interventions. There are a number of evaluative points regarding this technique, which are important to highlight here. First, ecological validity is limited by the use of video clips, which are removed from the real farm setting. However, the use of video footage with corresponding data allowed careful control over the experimental stimulus, which would not be possible in a real farm setting. Furthermore, by using pre-existing footage and data, we were able to avoid the use of animals for the purpose of the study (supporting the 3Rs of animal research: [39]), and maximize the utilization and impact of existing data. Second, although the self-reported measure of emotional response allowed for quick and easy data collection, this could be influenced by experimenter effects whereby participants might have responded in the way that they thought was being sought rather than how they really felt [40]. Future research could build upon the findings of this study by employing physiological measures of emotional response such as participant heart rate and galvanic skin response, which are less open to bias [41]. Third, the methodology allowed efficient data collection at pre-existing farmer discussion groups, as the procedure could be completed quickly with all group members participating simultaneously. Fourth, the method has quantified how well subjective scoring by observers compares to objective measures of the outcome of aggression (skin lesions and blood lactate). This makes the assumption that the objective measures are a closer approximation to the true experiences of the animal than the subjective scores but it is acknowledged that qualitative scores based on animal demeanor can also reflect welfare [42]. Finally, we did not include a non-professional group (e.g., consumers) as this was not within the aims of the current study. This study focused on how farmer exposure to pig aggression may have influenced their perceptions of aggression relative to others with experience of pigs (veterinarians) or with knowledge of agriculture but little experience of the pig industry (students). However, subsequent research examining consumer perceptions would be valuable.

5. Conclusions

Farmers were not desensitized to pig aggression. Farmers experienced a negative emotional response to seeing fights between pigs. They judged fights to be severe and exhausting for the animals and they were motivated to prevent them continuing. However, farmers and other observer groups underestimated the physical impact of aggression when they did not see the fight occurring and this may contribute to the limited uptake of methods to reduce aggression in commercial practice. Farmers are unlikely to see fights as frequently as they actually occur, and this likely limits their perception of aggression as a problem on their farm and their motivation to control aggression. In order to bridge the gap between research and practice, researchers must provide farmers with evidence of the economic and welfare impact of aggression as indicated by lesions, and farmers must be encouraged to estimate the impact of fights on their farm by counting lesions on the affected animals.

Supplementary Materials: Data for this project and the surveys are available at: https://osf.io/rh2sz/?view_only=d8b4c6f08e1448d487a4d204cf43077a.

Author Contributions: R.S.E.P. designed the experiment, conducted data collection, statistical analysis of the data, and writing of the original draft manuscript. S.P.T. provided supervision at all stages of the project, assisted with data collection, and reviewed and commented on the manuscript. I.C. provided supervision at all stages of the project and reviewed and commented on the manuscript. L.A.B. conducted data collection and reviewed and commented on the manuscript. F.A. provided supervision, and reviewed and commented on the manuscript.

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Appendix A

Stepwise selection of video clips

The final six video clips were selected using the following stepwise selection process:

- (1) Video clips were collected based on data obtained from research carried out by an SRUC project in 2015. The descriptive statistics for the full dataset can be found in Table A1.

Table A1. Descriptive statistics regarding measures of relative change in skin lesions (number of lesions per pig) and blood lactate (mmol/L) following the fight, compared to before the fight, for the entire dataset ($n = 168$).

Measure	Lesion Score	Blood Lactate
Mean	49.89	6.43
Min	0	−2.80
Quartile 1	6.00	0.53
Quartile 2	30.00	4.20
Quartile 3	74.75	10.80
Max	354	21.20

- (2) Pigs that displayed a negative relative change in blood lactate, and therefore displayed a reduction in blood lactate following the fight, were eliminated from analysis. In doing this, 26 pigs were eliminated. Descriptive statistics for the remaining dataset can be found in Table 1 (see Methods).
- (3) Criteria for the video clips were set based on quartiles. Video criteria can be seen in Table A2.

Table A2. Description of criteria used to identify video clips (LQ = lower quartile; IQR = interquartile range; UQ = upper quartile).

Clip	Focal Pig		Non-Focal Pig	
	Lesion Score	Blood Lactate	Lesion Score	Blood Lactate
1	IQR	IQR	IQR	IQR
2	LQ	LQ	LQ	LQ
3	IQR	IQR	IQR	IQR
4	UQ	UQ	UQ	UQ
5	IQR	IQR	IQR	IQR
6	IQR	IQR	No criteria set	

- (4) Contests that met the criteria for each clip were identified using the 'select cases' function in SPSS. The number of video clips to meet the criteria for each video clip can be seen in Table A3.

Table A3. Number of contests to meet the criteria for each video clip.

Clip	Number of Videos Identified
1	9
2	2
3	9
4	5
5	9
6	34

- (5) All potential video clips were then watched to identify the six clips that best matched the selection criteria described in Table A4.
- (6) Video clips were selected and Table 3 provides the exact objective measures for each of the pigs observed in the six video clips (see Methods).

Table A4. Description of video clip selection criteria and content (LS = lesion score).

Clip	Behaviour	Selection Criteria
1	<i>During fight:</i>	Both pigs engaged in mutual fighting behavior for a minimum period of 20 s. Both pigs remained in view of the camera for the duration of the 20 s. Both pigs obtained medium severity LS and lactate measures following the fight.
2	<i>After fight:</i>	During the 60 s immediately <i>after the fight ended</i> , both pigs were in view for a minimum period of 20 s. Both pigs displayed low severity LS and lactate measures following the fight.
3	<i>After fight:</i>	During the 60 s immediately <i>after the fight</i> , both pigs were in view for a minimum period of 20 s. Both pigs displayed medium severity LS and lactate measures following the fight.
4	<i>After fight:</i>	During the 60 s immediately <i>after the fight ended</i> , both pigs were in view for a minimum period of 20 s. Both pigs displayed high severity LS and lactate measures following the fight.
5	<i>During fight:</i>	During the 60 s immediately <i>before the fight ended</i> , both pigs engaged in mutual fighting behavior for a minimum period of 20 s. Both pigs remained in view of the camera for the duration of the 20 s. Both pigs obtained medium severity LS and lactate measures following the fight.
6	<i>During fight:</i>	During the 60 s immediately <i>before the fight ended</i> , one pig displayed bullying behavior whilst the other attempted to retreat for a minimum period of 20 s. Both pigs remained in view of the camera for the duration of the 20 s. The focal pig (recipient of bullying) obtained medium severity LS and lactate measures following the fight. No criteria were set for the non-focal (bullying pig) with regards to LS and lactate measures. This was because the two very different behaviors cannot be expected to result in the same measures.

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3. Conclusions

Frequent exposure to emotive stimuli can lead to desensitization whereby the recognition and response to a stimulus is inhibited (e.g. Carnagey et al., 2007; Anderson et al., 2010; Greitemeyer and Mugge, 2014; Brockmyer, 2015).

The purpose of this chapter was to establish the extent to which farmers recognise and differentiate severities of aggression, and whether this is influenced by their experience of working with pigs as compared to other observer groups. This chapter provides evidence that farmers' are efficient at recognising the impact of aggressive encounters in-action. However, farmers were inefficient at recognising and differentiating between different severities of aggression outcomes when they did not see the fight occurring. This was not determined by desensitization, as the perceptual and emotional response of farmers was comparable to the response of participants with knowledge of pigs but without any experience of working with them (agricultural and animal science students) and those with such experience (specialised pig veterinarians). This chapter provides the first investigation into farmers' perceptions of aggression and its outcomes and employed an innovative methodology whereby human perceptions were compared to objective measures of exhaustion (blood lactate) and injury (skin lesions) taken from the animals.

A number of limitations of this study's methodology were described in the published article in section '4.3 Evaluation of novel methodology'. However, a number of additional limitations regarding the participants sampled exist and are acknowledged here. First, there were some important demographic differences between our comparison groups. For example, pig farmers were predominantly male and were on average older than 40 years old, whilst animal science students were predominantly female and were on average younger than 25 years old. These demographic differences were unavoidable in order to maintain the representativeness of each population, but mean that I was limited in my capacity to assess the effects of age and gender. Second, the student populations were limited to one institution, therefore results cannot be generalised to student populations elsewhere. Third, the sample of specialist pig veterinarians was small due to difficulties in reaching this specialised demographic, and this could risk Type II errors due to a lack of statistical power. Fourth, social desirability bias is a risk inherent in social research such as this, and occurs when participants act in a way that they believe is favourable to others. Nevertheless, I did attempt to control this bias by ensuring that all participants knew that their responses were confidential and could not be tied to any individual, and I instructed participants not to discuss their answers with each other. Finally, I used comparison groups with and without experience of working with pigs in order to assess the

impact of farmers' experience on their perceptions. However, differences between the perceptions of these groups could be attributed to differences in their knowledge, interests, values and norms regarding livestock, rather than differences in their experiences. An alternative method would have been to use farmers' number of years' experience working with pigs. However, it is possible that relatively little experience (less than one year) would be required for desensitisation to occur, and this would not have been detected in such analysis. Furthermore, we did include age (which was highly correlated with number of years' experience) in the analysis, and found that older farmers were more motivated to intervene during aggressive encounters between pigs than younger farmers, providing further support for our conclusion that farmers are not desensitised to aggression.

This chapter makes important recommendations regarding the tools that farmers require in order to better recognise the issue, and thus motivate a change in practice. Specifically, researchers must provide farmers with evidence of the economic and welfare impact of aggression as indicated by lesions, and farmers must be encouraged to estimate the impact of fights on their farm by counting lesions on affected animals. However, it is important to note that recognition of the issue is unlikely to be sufficient to change

farmers' behaviour. Farmers willingness to improve animal welfare is known to be influenced primarily by economic factors (Bock and van Huik, 2007; Gocsik et al., 2015) but also by a wide range of other internal and external factors, such as attitudes, perceptions, social norms and socio-demographic characteristics (Hemsworth et al., 1994; Willock et al., 1999; Coleman et al., 2000; Hemsworth, 2003; Alarcon et al., 2014). The following research chapter provides an in-depth analysis of the range of factors that may influence farmers' decisions regarding aggression, in order to identify targets for initiating a change in practice.

Supplementary materials: The survey for farmers and non-farmers can be found in appendices C and D respectively.

Chapter 5: Factors influencing farmer willingness to reduce aggression between pigs

1. Introduction

Farmers' behaviour regarding aggression between pigs is likely to be influenced not only by their ability to recognise this aggression as a welfare and production problem (Chapter 4), but also by a wide range of other internal and external factors relating to their personal characteristics and context. Understanding which social factors (e.g. attitudes, socio-demographic characteristics, social norms) are important, and how they interact, is essential for developing effective evidence-based interventions. Social scientists have developed a variety of models (e.g. the Theory of Planned Behaviour; Ajzen, 1985) which attempt to understand the determinants of human behaviour in specific contexts (review article: Davis et al., 2015), and these models have been applied to farmers' behaviour regarding animal welfare (e.g. Kauppinen et al., 2012; Brennan et al., 2016; Richens et al., 2018). The current chapter consists of a description of human behaviour change research and an example of how it has been applied to farmers' behaviour (Section 2). After that, a published questionnaire study is inserted which (1) establishes the current practice of UK and Irish pig farmers with regards to aggression between pigs and (2) identifies the factors

that influence farmers' willingness to reduce aggression (Section 3). Finally, the chapter ends with an acknowledgement of the study limitations (Section 4) and concluding remarks (Section 5).

2. Changing human behaviour

Human behaviour is complex and influenced by a wide range of factors (Davis et al., 2015). In order to change human behaviour it is necessary to have a theoretical understanding of the determinants of that behaviour. Here, insight can be provided from the field of social science where as many as 82 models of human behaviour have been identified and applied to a myriad of behaviours relating to public health, and social and environmental issues (review article: Davis et al., 2015). Most of these theories have been applied very little, and few theories dominate the literature. The Theory of Reasoned Action (TRA) (Ajzen and Fishbein, 1980) and its extension, the Theory of Planned Behaviour (TPB) (Ajzen, 1991) are two of the most commonly used models employed by those interested in understanding human behaviour in specific contexts. The TRA and the TPB assume that a person's intention to perform a specific behaviour determines the likelihood that the behaviour will occur (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980; Ajzen, 1985; 1991). In turn, the TPB assumes there are three

determinants of intentions; these are a person's attitudes, perceived behavioural control, and subjective norms (Figure 1). The TRA does not include perceived behavioural control as a factor. Attitudes are affected by beliefs about the outcome of performing the behaviour, and the value one gives to this outcome. Perceived Behavioural Control (PBC) refers to beliefs about the presence of factors that may facilitate or impede performance of the behaviour (Ajzen, 1985). This relates to internal factors, such as a person's perception of their own knowledge, skills and abilities, as well as external factors, such as time, opportunity and dependence on others (Ajzen, 1985). Subjective norms are beliefs about the expectations of others, for example perceived social pressure. The more favourable the attitude and the subjective norm, and the greater the perceived behavioural control, the stronger the intention to perform the behaviour. Given a sufficient degree of actual control, people are expected to carry out the behaviour when the opportunity arises (Ajzen, 1991).

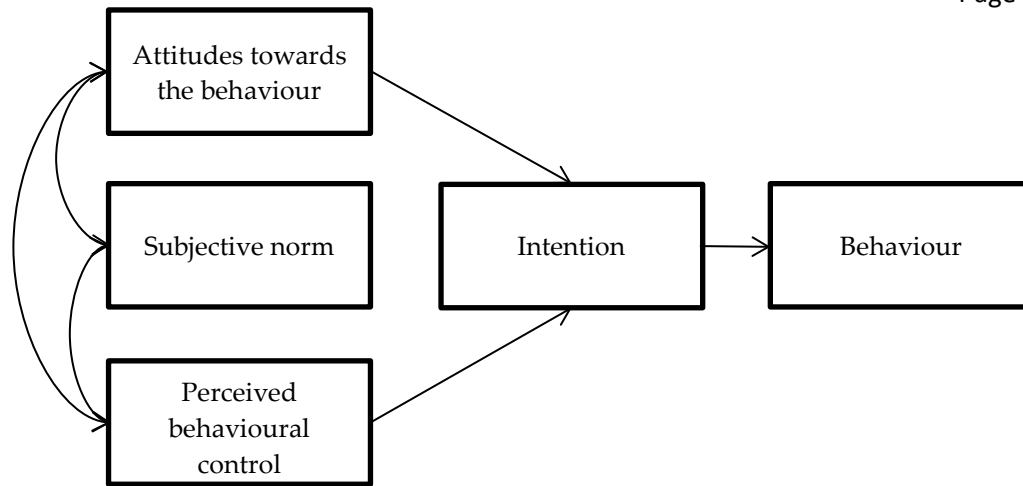


Figure 1. Conceptual framework for the prediction of specific intentions and behaviours according to the Theory of Planned Behaviour. Modified from (Ajzen, 1991)

Many studies carried out in the agricultural sector have used or adapted the TPB for the investigation of farmers' behaviours. For example, with regard to disease control (Brennan et al., 2016; Richens et al., 2018), antibiotic use (Jones et al., 2015), housing systems (de Lauwere et al., 2012) and dairy cow foot health (Bruijn et al., 2013). Brennan et al (2016) and Richens et al (2018) both applied the TPB to investigate why dairy farmers do not adequately implement biosecurity practices despite them being frequently highlighted as important to ensure the health and welfare of their animals. In the study of Brennan et al (2016) twenty-five British farmers were qualitatively interviewed using the TPB framework, whilst in the study of Richens et al (2018) 757 British farmers completed a quantitative paper-based survey designed using the TPB components. Both of these studies highlighted the importance of attitudes towards disease prevention, and how much

implementation control farmers believe that they have. Farmers distrusted the accuracy of diagnostic tests, questioned the effectiveness and time-efficiency of practices, and misunderstood how diseases can be transmitted (Brennan et al., 2016). Although farmers perceived that they had the ability to control disease when it occurred, they did not necessarily perceive preventing disease as in their control, viewing it as an inevitability (Richens et al., 2018). Furthermore, social norms, particularly regarding communication between the farmer and veterinarian, were a key area affecting uptake in practice (Brennan et al., 2016; Richens et al., 2018). By investigating the factors that influence dairy farmer behaviour regarding biosecurity measures, several motivators and barriers were identified, and the authors were able to identify key targets for interventions to improve uptake of biosecurity measures in practice. Specifically, the authors recommended that guidance about the control and prevention of disease should be provided, and industry stakeholders (particularly veterinarians) should be aware of farmers' beliefs and attitudes in order to target communication and advice accordingly. The following publication employs a similar approach whereby pig farmers' behaviour regarding pig aggression is investigated in order to identify targets for initiating a change in practice.

3. Journal article

Declaration

Rachel Peden designed this study, collected data, analysed data and wrote the original version of the manuscript. Simon Turner and Laura Boyle helped to collect data at farmer discussion groups. Faical Akaichi explained and demonstrated how to conduct structural equation model analysis on the dataset. Rachel Peden then identified the final variables to be included, and ran the final model. All additional analyses were conducted by Rachel Peden. Simon Turner, Faical Akaichi, Irene Camerlink and Laura Boyle provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to external peer review comments and prepared the response letter for the journal and was the corresponding author. Inclusion of this publication complies with copyright laws. Permission from co-authors was obtained regarding the inclusion of this article in the current thesis.

Article

Factors Influencing Farmer Willingness to Reduce Aggression between Pigs

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Simple Summary: Aggression between pigs is an important animal welfare issue in commercial farming, and is caused by an unstable social structure due to regular regrouping of unfamiliar pigs. The behavior has been extensively researched and several strategies to reduce aggression have been identified, however, they are not commonly used by farmers in practice. We conducted a survey of 122 UK and Irish pig farmers with the aim of understanding why farmers do not adequately implement aggression control strategies. This was important in order to identify targets for encouraging a change in practice. We found that the majority of farmers mixed pigs at least once during production and had tried at least one mitigation strategy in the past. However, farmers expressed limited willingness to implement strategies in the future, and this was influenced by: (1) their beliefs about the outcome of controlling aggression; (2) their perception of their ability to implement the necessary changes; (3) their perceptions of aggression as a problem and; (4) their views of relevant stakeholder groups. Based on these findings we make important recommendations on how to bridge the gap between research and practice.

Abstract: Aggression between pigs remains an important animal welfare issue despite several solutions existing. Uptake of livestock welfare research relies on various stakeholders being willing to recommend or adopt changes to farm structure or management (e.g., veterinarians, researchers, farmers). This survey provides insight into the attitudes and practices of 122 UK and Irish pig farmers regarding aggression between growing pigs. Our aim was to understand why mitigation strategies are not adequately implemented. The majority of farmers mixed pigs at least once during production and had tried at least one mitigation strategy in the past. Farmers expressed limited willingness to implement strategies in the future, and a structural equation model revealed that this was directly influenced by their beliefs about the outcome of controlling aggression, and their perception of their ability to implement the necessary changes. Willingness was indirectly influenced by their perceptions of aggression as a problem and views of relevant stakeholder groups. Veterinarians had the greatest impact on farmer behavior. We recommend that researchers test research findings in practice, calculate cost-benefits of implementation, and transfer knowledge through various sources. This study showed that structural equation modeling is a valuable tool to understand farmer behavior regarding specific and entrenched animal welfare issues.

Keywords: animal welfare; decision-making; farmers; pigs; structural equation model

1. Introduction

Aggression between pigs is one of several animal welfare issues where there is resistance to change in practice despite extensive research [1,2]. The implementation of animal welfare research relies on a variety of relevant stakeholders. For example, researchers must effectively communicate their findings to the industry, and farmers and veterinarians must be willing to adopt these recommendations. It is therefore important to understand the decision-making process of farmers, in order to identify targets for initiating a change in practice.

Pig aggression primarily occurs as a result of the unstable social structure created by regrouping, as pigs fight in order to re-establish dominance relationships [3]. Aggression threatens animal welfare and the economic sustainability of the production system through injuries such as skin lesions [3] and the transient effects of stress upon immune responses [4], growth rate [5] and susceptibility to infection [6]. For some producers, regrouping is unavoidable in order to maximize use of space. Furthermore, farmers attempt to create groups of pigs with equal body size which market simultaneously. Nevertheless, it is possible to limit the occurrence and intensity of aggression by implementing various mitigation strategies (review articles: [2,7–9]). For example, allowing litters to co-mingle (i.e., socialization) prior to weaning [10,11], housing pigs in relatively large groups [12], providing a diet high in tryptophan [13] and providing sufficient space [14] can all help control aggression at regrouping, but are employed by only a minority of farmers [2,15]. It is well established that a range of interrelated internal and external factors influence farmer behavior regarding animal welfare, such as personal values and attitudes, and financial and practical constraints (e.g., [16]). However, the literature on farmer behavior towards most welfare issues, including aggression, is scarce. This study aimed to: (1) explore the attitudes and behavior of UK and Irish pig farmers regarding aggression between pigs and; (2) investigate the factors that influence farmer willingness to implement aggression control strategies. The causal relationships amongst observed and latent variables were estimated by using structural equation modeling. We hypothesized that a range of interrelated factors influence farmer willingness to implement aggression control strategies.

2. Research Hypotheses

We reviewed the literature on farmers' decisions regarding animal welfare in order to formulate hypotheses on the factors that influence farmer willingness to control pig aggression. Much of this literature uses the framework of the Theory of Planned Behavior which describes willingness to make a behavioral change as being influenced by attitudes, perceived behavioral control and subjective norms [17,18]. The literature identifies wide ranging factors which can influence farmers' animal welfare decisions, and the following hypotheses are representative of these findings.

Hypothesis 1. *Perceiving positive outcomes of controlling aggression has a positive influence on farmer willingness to control pig aggression.*

A number of studies indicate that farmer decisions are influenced by beliefs about the outcome of an intervention, and the value the farmer gives this outcome [19–21]. Beliefs about the economic outcomes are particularly important; as the main incentive to participate in animal welfare schemes is an expected improvement in profitability and market access [21]. The most important barrier is distrust in the economic advantages of doing so [21,22].

Hypothesis 2. *Perceiving the possibility to control aggression has a positive influence on farmer willingness to control pig aggression.*

Beliefs about the presence of factors that may facilitate or impede implementation of an animal welfare innovation are fundamental in farmers' decision-making processes [19,20,23]. This relates to internal factors, such as a person's perception of their own knowledge, skills and abilities, as well as external factors, such as time available and dependence on others. Farmer willingness to change current farm practice is limited when they perceive a lack of time, skilled labor, or knowledge [23–25], or if the welfare innovation is perceived to be unaffordable or difficult to practically manage [26].

Hypothesis 3. *Valuing the opinion of relevant stakeholders regarding aggression has a positive influence on farmer willingness to control pig aggression.*

Putting a high value on the opinion of peers, researchers or specialists and feeling that peer-pressure and/or authorities expect improvements in animal welfare, is linked to greater willingness to provide high welfare standards [19,20,27]. Stakeholders differ in their impact on farmer behavior, with veterinarians being particularly influential [27] whilst researchers are distrusted [28].

Hypothesis 4. *Perceiving aggression as a problem on their farm has a positive influence on farmer willingness to control pig aggression.*

Pig farmer perceptions are strong predictors of their behavior [29–32] and a recent survey of 167 UK pig farmers found that the majority do not perceive aggression as a problem that needs to be addressed [33]. As farmers are unlikely to invest resources in a change that they do not believe is necessary, this is likely to severely limit their motivation to control the issue.

The literature directed us to these four specific hypotheses, however, since relatively little is known about the complex decision process we acknowledged that other causal links may exist that were not specifically hypothesized. Causal relationships among variables are likely to be complex and interrelated, for example, variables may influence farmer willingness to improve animal welfare directly or indirectly (through their effect on other variables, which subsequently directly influence willingness to improve animal welfare), and we take this into consideration during our statistical analysis.

3. Materials and Methods

3.1. Data Collection

A total of 133 commercial pig farmers either completed or partially completed a survey (described in Section 3.2. Measures). Farmers were recruited by a range of means between February–December 2017. Firstly, a paper version of the survey was distributed via post to a sample of farmers that previously participated in aggression research conducted at Scotland's Rural College (SRUC) ($n = 170$) and resulted in a 28.8% response rate ($n = 49$). Participants were also recruited at six farmer events organized by SRUC ($n = 16$), Teagasc ($n = 28$) and the Agricultural and Horticultural Development Board Pork (AHDB Pork) ($n = 33$). Finally, an online version of the questionnaire was created using Survey Monkey and the URL was distributed with the postal survey, and by contacts in the Pig Veterinary Society and the Weekly Tribune. All farmers were unaware of the project and unaware that they would be asked to complete the survey prior to being contacted. We chose to use both a paper and online survey in order to maximize our response rate by allowing farmers to choose their preferred method of participation. Responses to the online survey were low ($n = 7$). This is consistent with previous research which found a poor response of farmers to an online survey compared to a paper survey [34] and should be considered in future surveys of farmers. Those recruited at farmer events were unaware that they would be asked about the topic of aggression prior to attending, therefore these farmers were unlikely to introduce bias into the sample. However, those who voluntarily responded via post or online were likely to be progressive and interested in the survey topic. These farmers may, therefore, have introduced some bias into the sample.

3.2. Measures

The survey comprised of three main sections entitled: (1) mixing aggression; (2) farm demographics; and (3) personal demographics (see Supplementary Materials). The first section contained all items used to measure each observed and latent variable included in the structural equation model (described in Section 3.4. Data analysis). These were three items measuring farmer outcome beliefs about controlling aggression, nine items to measure social influence, four items to measure perceived possibility to control aggression, one item to measure participants' perception of aggression as a problem on their farm and one item to measure their willingness to implement aggression control strategies. They were also asked which aggression control strategies they had tried and how useful they found them to be (from 1 = 'not useful at all' to 7 = 'very useful') (all statements used in the model are shown in Table 1). In addition, farmers were asked for their level of agreement/disagreement (from 1 = 'strongly disagree' to 7 = 'strongly agree') with the statement 'mixing aggression is a problem for the industry'. By using a 7-point Likert type scale, farmers were not forced to agree/disagree as they were able to provide a neutral response (4 = 'neutral'). We chose to include the neutral response because farmers may have been either unopinionated or unfamiliar with certain content. Farm information was collected regarding location, quality assurance scheme membership, farm size (number of pigs), housing system (indoor/outdoor/combined), average group size, and at what stages of production pigs are mixed. Personal demographic information was collected regarding age, gender, role on farm, and years of experience working with pigs. Prior research shows that farmers interpret tail biting and mixing aggression as interchangeable terms [28,33] even though the two behaviors have different causes [35,36]. Therefore a clear definition of mixing aggression was provided, and participants were instructed not to include tail biting in their answers. The survey was piloted with 8 pig farmers and 17 researchers and amended according to their feedback regarding the wording and appropriateness of questions. This study was conducted in accordance with the Declaration of Helsinki. This study received internal ethical approval from the Human Ethical Review Committee at the University of Edinburgh (Project identification code: HERC_66_16), and informed consent was obtained for all participants.

3.3. Socioeconomic Characteristics of the Final Sample

It was necessary for the full dataset to be analyzed and therefore participants who only partially completed Section 1 of the survey were removed. Of the 133 responses, only 122 completed all questions, and the others were not included in the data analysis. The majority of the final respondents were male (73.8% male; 12.3% female; 13.9% undisclosed), on average 47 ± 15.05 years old (min 17; max 82) and with 26 ± 16.24 years of experience working with pigs (min 1; max 70). Of the respondents, 41.8% were farm owners, 18.9% were managers and 23% were farm workers. The remaining respondents were contract farmers (4.1%), retired (5.7%) or chose not to disclose their role (6.6%). All farmers, regardless of their role on the farm, were capable of making changes to pig husbandry which would directly influence aggression (e.g., by avoiding mixing unfamiliar pigs). Opportunities to make changes may be more constrained for those who do not have a management role. Nevertheless, the responses of all of the surveyed farmers were relevant due to their current or past experience of pig husbandry.

The study was carried out across the UK and Ireland, with 54.1% of respondents based in England, 16.4% in Scotland, 2.5% in Wales, 3.3% in Northern Ireland, 18.9% in the Republic of Ireland and 4.8% undisclosed. Red Tractor was the most common quality assurance scheme, assuring 54.1% of the surveyed farms, followed by RSPCA (23.8%), Assured British Pigs (14.8%), Quality Meat Scotland (13.9%), Scottish SPCA (8.2%) and Genesis Quality (6.6%). Some of the farmers reported having no quality assurance scheme (13.9%), whilst 11.5% indicated that they were assured by another scheme (ticked 'other') but they did not specify which one. Some farms were assured by more than one scheme.

Table 1. Statements used to measure outcome beliefs about controlling aggression (OB), social influence (SI), perceived possibility to control aggression (PP), total number of aggression control strategies tried (NST), perception of aggression as a problem (PERC) and willingness to control aggression (WILL).

	Item	Statement	Scale
Outcome beliefs (OB)	OB ₁	A reduction in mixing aggression would create more profit for my farm	1 = strongly disagree to 7 = strongly agree
	OB ₂	A reduction in mixing aggression would improve animal welfare on my farm	
	OB ₃	A reduction in mixing aggression would improve my job satisfaction	
Social Influence (SI)		<i>How much does the opinion of this person/group affect your decisions with regard to mixing aggression?</i>	
	SI ₁	Veterinarians	1 = not at all to 7 = very much
	SI ₂	Researchers	
	SI ₃	Wholesale/retail trade	
	SI ₄	Agricultural advisor	
	SI ₅	Slaughterhouse staff	
	SI ₆	Consumers	
	SI ₇	Other pig farmers	
	SI ₈	Quality assurance body	
	SI ₉	Levy body	
Perceived possibility (PP)	PP ₁	I am aware of methods to reduce mixing aggression	1 = strongly disagree to 7 = strongly agree
	PP ₂	I or my colleagues have the possibility to make changes in management which would reduce mixing aggression	
	PP ₃	I or my colleagues have the time available to reduce mixing aggression	
	PP ₄	I have the financial resources to reduce mixing aggression	
Perception (PERC)	PERC	Mixing aggression is a problem on my farm	1 = strongly disagree to 7 = strongly agree
Number of strategies tried (NST)		<i>Please indicate which technique(s) you have tried to minimize aggression between growing/finishing pigs:</i>	
		Purposely mix pigs from neighboring pens	Yes/no
		Odor masking agents	
		Barriers or get-way areas e.g., adding straw bales	
		Evening/night time mixing	
		Distraction material/toys	
		Pre-weaning socialization/allowing litters to mix before weaning	
		Mixed-weight pens	
		Mix into large groups	
		Stresnil/azaperone (a sedative)	
		Other (please specify)	
Willingness (WILL)	WILL	In the near future how likely are you to implement strategies to reduce mixing aggression between growing/finishing pigs?	1 = not likely at all to 7 = very likely

Farms on average kept 3625 growing/finishing pigs at any given time, and the majority of pigs were housed indoors (see Table 2 for information on farm size and housing system). Of the 71 farmers who reported average group size for growing/finishing pigs, only 25 kept pigs in conventional groups of 25 or smaller. On average growing/finishing pigs were kept in groups of 85.6 ± 121.92 (min 12; max 600). Of the 122 participants, 74.6% were farrow-finish, 3.3% were wean-finish and 4.9% were grow-finish; whilst 16.4% did not provide sufficient information.

The sample is roughly representative of UK agricultural workers which are mainly males around 59 years of age [37]. Farms showed a wide range in size and were based mainly in England, which is also representative of the UK population (53% of the UK breeding farms have between 250 and 749 sows and 85% are based in England [38,39]).

Table 2. Mean number of pigs per farm at any moment in time and housing system for weaners, grower/finishers, lactating and dry sows.

Stage of Production	Mean Number of Pigs $\pm$ Std. (Number of Farmers to Disclose)	Range	Housing Percentage (Number)			
			Indoor	Outdoor	Combined	Undisclosed
Weaners	3252 $\pm$ 5736.8 (91)	0 *–40,008	68.9% (84)	5.7% (7)	4.9% (6)	19.7% (24)
Growers; Finishers	3625.2 $\pm$ 4382.7 (92)	0 *–23,300	74.6% (91) 73.8% (90)	4.1% (5) 2.5% (3)	3.3% (4) 4.1% (5)	18% (22) 19.7% (24)
Lactating Sows; Dry Sows	959.6 $\pm$ 1722.4 (96)	0 *–12,500	60.7% (74) 62.3% (76)	14.8% (18) 12.3% (15)	3.3% (4) 4.1% (5)	20.5% (25) 20.5% (25)

* Some farmers reported keeping zero pigs either because they do not keep this stage of production or because they are now retired.

3.4. Data Analysis

3.4.1. Overview

The method used in this study was Structural Equation Modeling (SEM) which has been used previously to explore the attitudes and behavior of farmers [19] and consumers [40] towards animal welfare in general. The method has also been used to explore farmer decisions regarding specific issues such as nitrate pollution [41] and participation in organic farming programs [42]. However, this method has never been used to tackle farmer behavior regarding specific and entrenched animal welfare issues. SEM uses observed and latent variables whereby the latent variables are not directly observed but are inferred from multiple indicator variables. Observed variables are single indicator variables. SEM tests the causal links specified in a theoretical model and describes the nature and magnitude of the relationship between latent and observed variables [43]. SEM takes into account both direct and indirect causal relations. To test the proposed model the two-step approach proposed by [44] was used. Firstly, confirmatory factor analysis was employed to confirm that observed variables (i.e., responses to specific items) loaded onto latent variables in a manner that supported the definition of the latent variable (e.g., outcome beliefs about controlling aggression). This step defined the measurement model. The second step involved assigning the relevant relationships among variables (latent and observed) to build and test the structural model. Therefore the term SEM refers to the full model which consists of two types of model: the measurement model and the structural model. These steps are described in more detail in following sections. SEM analysis was conducted using the statistical package Stata (version SE 15, StataCorp, TX, USA).

All additional analyses were conducted using SPSS (version 22, International Business Machines Corp, Armonk, NY, USA). Specifically, associations between items on a 7-point Likert type scale were assessed using Spearman Rank correlation coefficient. Wilcoxon signed-rank tests were used to determine the median difference between two paired or matched observations (e.g., farmer agreement with the statement ‘mixing aggression is a problem on my farm’ compared to ‘mixing aggression is a problem for the industry’). Friedman tests were used to determine median differences between three or more matched observations (e.g., comparing farmer responses to ‘How much does the opinion of this person/group affect your decisions with regard to mixing aggression?’ for each of the nine stakeholder groups). Kruskal-Wallis tests were used to determine differences between three or more independent observations (e.g., comparing the perceived usefulness of each of the nine aggression control strategies as judged by the specific farmers who had tried them). Significant results were followed up with pairwise comparisons with a Bonferroni correction for multiple comparisons. To determine the impact of farm location (England, Scotland, Wales, Northern Ireland, Republic of Ireland) on practice regarding aggression we ran a chi-square test whereby the dependent variable was experience of trying an aggression control strategy in the past (yes/no). To determine the impact of farm location on

willingness to implement aggression control strategies we used cumulative odds ordinal logistic regression with proportional odds. The assumptions of (i) no collinearity between independent variables and (ii) proportional odds were checked through inspection of collinearity diagnostics and the full likelihood ratio test. To determine whether there was a relationship between farm size (number of growing/finishing pigs) and willingness to implement aggression control strategies we used Spearman's rank correlation coefficient. Results were considered significant where $p < 0.05$ for all tests. Where responses on the 7-point Likert type scale were pooled (e.g., in order to describe the percentage of participants to agree with a statement); points 1–3 were coded as 'disagree'; 4 was coded as neutral and; 5–7 were coded as 'agree'.

3.4.2. Measurement Model (MM)

The first step involved performing confirmatory factor analysis for the following latent variables: (1) outcome beliefs about controlling aggression (OB); (2) social influence (SI) and; (3) perceived possibility to control aggression (PP). The purpose of this step was to confirm that variables assumed to describe a latent variable did so (see Table 1 for individual variables included in each factor). We undertook separate confirmatory factor analysis (CFA) for each latent variable. Convergent validity of each latent construct was verified by checking: (1) the magnitude and direction of standardized factor loadings which indicate the relationship of each variable to the underlying factor (a minimum threshold of 0.5 was set); (2) the Cronbach alpha coefficient which indicates internal consistency of variables within a factor (which should be >0.6); (3) the average variance extracted (AVE, which should be $>50\%$) and; (4) composite reliability which provides another measure of internal consistency (CR, which should be >0.7) [45,46]. Discriminant validity indicates whether variables that are not supposed to be related are actually unrelated and was checked by assessing the squared correlation between latent constructs (SC, which should be $<AVE$). To check validity of the measurement model a range of diagnostic parameters were used. Firstly, the ratio of the chi-square (χ^2) to the degrees of freedom (df) should not exceed 3. We also checked the root mean square error of approximation (RMSEA, which should be <0.05), the comparative fit index (CFI, which should be <0.90) and the standardized root mean squared residual (SRMR, which should be <0.08) [47].

3.4.3. Structural Model

After obtaining a satisfactory measurement model, we defined and ran the structural model using robust maximum likelihood analysis. The purpose was to estimate the relationships among and between number of strategies tried (NST), perception of aggression as a problem (PERC), willingness to control aggression (WILL) and the latent variables (OB, SI and PP) in order to test our hypotheses and advance our understanding of the complex relations among constructs. The literature directed us to four specific hypotheses (Section 2), however, since relatively little is known about the complex decision process we acknowledged that other causal links may exist that were not specifically hypothesized. Therefore we did not constrain the SEM to look only at the relationships hypothesized a priori to exist, and we estimated all possible relationships between NST, PERC, WILL, OB, SI and PP.

4. Results

4.1. Attitudes and Current Practice

Almost all of the respondents (99.2%) reported avoiding mixing growing/finishing pigs wherever possible (see Figure 1). Nevertheless, only 5.7% of farmers reported never mixing unfamiliar growing/finishing pigs during production; 45.9% of farmers reported mixing once, 28.7% mix twice, 6.6% mix three times and one farmer mixed four times during each production cycle. Growing/finishing pigs were most commonly mixed at weaning (56.6%), followed by grower (28.7%), slaughter (23.8%) and finisher stages (16.4%). Nine percent of the farmers also indicated that they regroup pigs at other stages of production. Of those that specified the timing of this mixing,

both reported regrouping the remaining pigs that were not yet big enough to be sent for slaughter ($n = 2$).

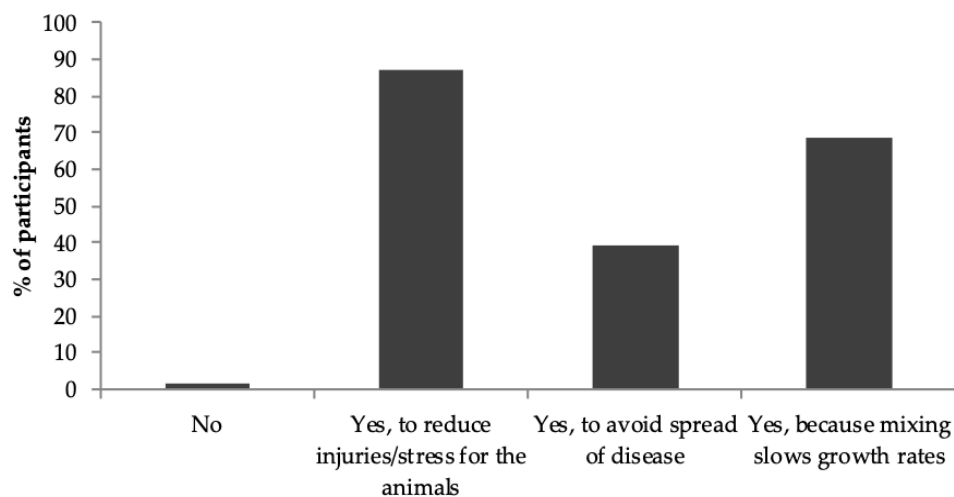


Figure 1. Percentage of farmers to tick each statement in response to the following question: ‘Do you avoid mixing unfamiliar growing/finishing pigs as far as practically possible? Please tick all that apply’.

Farmers were more likely to agree that aggression was a problem for the industry (51.6% agreed; median response = 5) than for their own farm (14.8% agreed; median response = 3) ($z = 5.582$, $p < 0.0001$). Farmers (84.4%) were aware of methods to reduce mixing aggression. Half of them (50%) believed they had the possibility to make changes in management and 38.5% believed that they had time available to reduce mixing aggression. Of the farmers who indicated having responsibility for making financial decisions ($n = 88$), 39.8% believed that they had the financial resources to control mixing aggression. Most farmers (88.5%) had tried at least one strategy to control aggression when mixing growing/finishing pigs, with respondents selecting between one and nine techniques (1: $n = 8$; 2: $n = 17$; 3: $n = 30$; 4: $n = 22$; 5: $n = 14$; 6: $n = 8$; 7: $n = 4$; 8: $n = 4$; 9: $n = 1$). There was no effect of farm location (country) on likelihood of having tried a strategy ($p > 0.05$). The most used strategy was distraction material/toys (73.8%) whilst the least used strategy was the application of sedation (13.1%) (Table 3). There was a statistically significant effect of strategy on the perceived usefulness of each strategy ($\chi^2(8) = 21.016$, $p < 0.05$). Pre-weaning socialization was perceived as more useful than mixed weight pens ($p < 0.05$) and purposely mixing from neighboring pens ($p < 0.05$) (Table 3). In addition to those strategies listed in the survey, farmers also used the comments section to emphasize the important link between genetics and aggression ($n = 3$). Moreover, two farmers reported using water sprinklers to control aggression at mixing.

Table 3. Percentage of respondents who had tried each aggression mitigation strategy and the median usefulness score for each strategy (from 1 = not useful at all to 7 = very useful). Different letters indicate significantly different usefulness scores at $p < 0.05$.

Aggression Mitigation Strategy	Percentage Tried (Number)	Median Usefulness Score (1–7)
Purposely mixing pigs from neighboring pens	34.4% (42)	4 ^b
Odor masking agents	38.5% (47)	4.5 ^{a,b}
Barriers or get away areas	40.2% (49)	5 ^{a,b}
Evening/night time mixing	15.6% (19)	5 ^{a,b}
Distraction material/toys	73.8% (90)	5 ^{a,b}
Pre-weaning socialization	38.5% (47)	6 ^a
Mixed-weight pens	21.3% (26)	4 ^b
Mix into large groups	45.1% (55)	5 ^{a,b}
Stresnil/azaperone (sedative)	13.1% (17)	5 ^{a,b}

More than half of the participants (54.9%; $n = 67$) believed that a reduction in mixing aggression would create more profit for their farm, whilst 58.2% ($n = 71$) believed it would improve animal welfare and 57.4% ($n = 70$) believed it would improve their job satisfaction. Farmers stated that they were influenced by different stakeholders to different degrees ($\chi^2 (2) = 195.917, p < 0.001$). Veterinarians had a greater influence on farmer behavior than any other stakeholder ($p < 0.01$), whilst other pig farmers and quality assurance bodies had a significantly greater influence than the wholesale/retail trade, slaughterhouse staff, consumers and levy bodies ($p < 0.01$) (see Figure 2). Fewer than half (41%) of participants indicated that they were willing to implement aggression mitigation strategies in the future. This was unaffected by farm location ($p > 0.05$) or number of growing/finishing pigs ($r = -0.132, p > 0.05$).

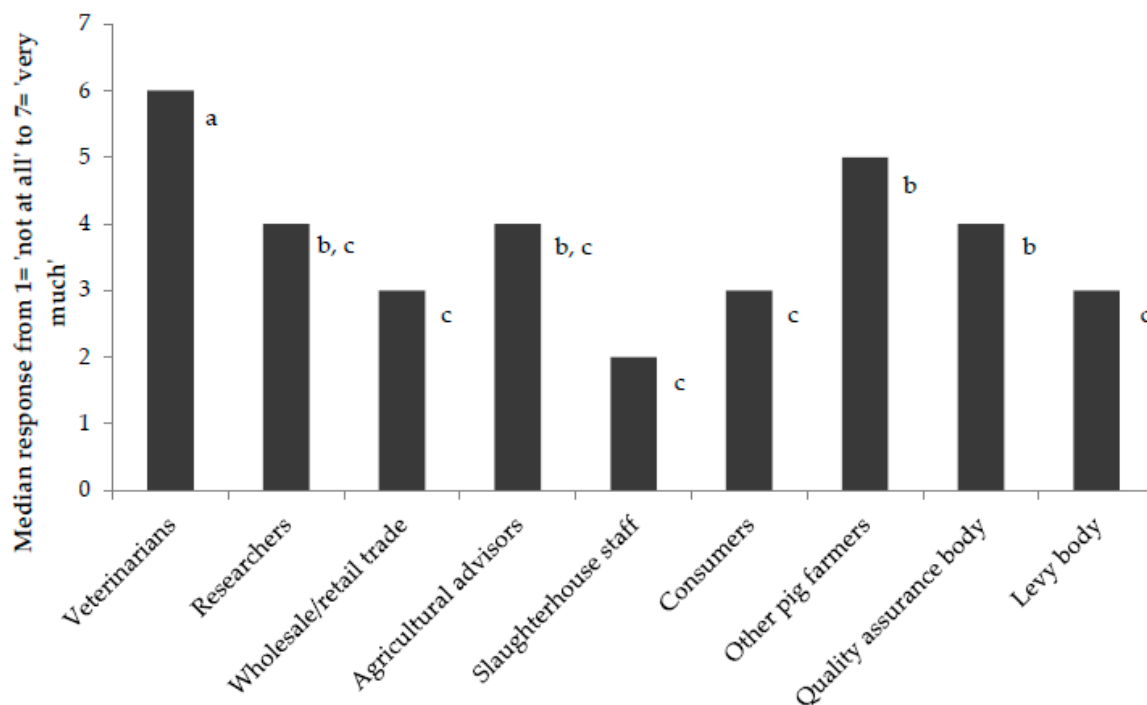


Figure 2. Farmers' median response to the question: 'How much does the opinion of this person/group affect your decisions with regard to mixing aggression?' (from 1 = 'not at all', to 7 = 'very much'). Letters indicate results of post-hoc pairwise comparisons whereby different letters indicate a significant difference between groups at $p < 0.05$.

4.2. Measurement Model

As mentioned in Section 2 the first step of the SEM was to carry out confirmatory factor analysis to identify latent constructs for: (1) outcome beliefs about controlling aggression (OB); (2) social influence (SI) and; (3) perceived possibility to control aggression (PP). Confirmatory factor analysis revealed that the four PP questionnaire items did not load onto a common construct, and this could not be improved by adding or removing individual variables. As a result, we employed PP₂ ('I or my colleagues have the possibility to make changes in management which would reduce mixing aggression') as an observed variable; of the four PP items PP₂ was deemed the most capable of fully representing this construct. We identified and extracted the two remaining latent variables (SI and OB) measured by 12 indicator variables. Reliability of factor loadings were high (standardized factor loadings were above 0.5) for all observed variables forming these latent constructs with the exception of SI₂ which fell below the 0.5 threshold at 0.41. The slightly lower standardized factor loading for this variable is due to the fact that veterinarians (SI₂) had a significantly greater influence on farmer behavior when compared to any other stakeholders (Figure 2). This variable was retained in the model due to its theoretical significance as indicated by prior research [27]. The Cronbach alpha coefficient (>0.6), CR (>0.7) and AVE ($>50\%$)

all confirmed good internal consistency for both latent variables [45,46]. Results of the standardized factor loadings, average variance extracted (AVE) and composite reliability are shown in Table 4. Discriminant validity was confirmed by assessing the SC between latent constructs (which should be $< \text{AVE}$). Validity of the measurement model was confirmed through the χ^2 and the ratio χ^2/df (< 3), RMSEA (< 0.08), CFI (> 0.9) and SRMR (< 0.08) which all indicated a good model fit (see Table 4).

Table 4. Reliability of the standardized confirmatory factor analysis.

Construct	Indicators	Standardized Loadings (Std Error)	Composite Reliability (AVE)	Measurement Model
Outcome beliefs about controlling aggression (OB)	Cronbach's <i>a</i>	0.93	0.93 (0.813)	$\chi^2 = 85.24$ df = 53 $\chi^2/\text{df} = 1.61$ RMSEA = 0.071 SRMR = 0.053 CFI = 0.962 SC = 0.027
	PO ₁	0.88 (0.03)		
	PO ₂	0.96 (0.02)		
	PO ₃	0.86 (0.04)		
Social Influence (SI)	Cronbach's <i>a</i>	0.90	0.90 (0.512)	
	SI ₁	0.41 (0.08)		
	SI ₂	0.71 (0.06)		
	SI ₃	0.76 (0.06)		
	SI ₄	0.80 (0.05)		
	SI ₅	0.69 (0.06)		
	SI ₆	0.80 (0.04)		
	SI ₇	0.67 (0.07)		
	SI ₈	0.76 (0.05)		
	SI ₉	0.74 (0.06)		

4.3. Structural Model

After a satisfactory measurement model was obtained, a structural model was estimated. The results can be seen in Figure 3. Latent variables are represented by ovals and observed variables are represented by rectangles in the path diagram. All possible relationships between observed and latent variables were estimated, and only relationships whereby $p < 0.10$ are displayed. All regression coefficients presented were positive. The regression coefficient revealed that OB was the largest determinant of WILL; furthermore OB affected WILL indirectly through PP. Therefore H1 (perceiving positive outcomes of controlling aggression has a positive influence on farmer willingness to control aggression) is supported. The regression coefficient of PP on WILL was also positive and significant. Therefore H2 (perceived possibility to control aggression has a positive influence on farmer willingness to control aggression) is also supported. The direct regression coefficient of SI on WILL was not significant; therefore H3 (valuing the opinion of relevant stakeholders regarding aggression has a positive influence on farmer willingness to control aggression) is not entirely supported. However, there was a significant indirect relationship between SI and WILL through PP. The direct regression coefficient of PERC on WILL was not significant; therefore H4 (Perceiving aggression as a problem on their farm has a positive influence on farmer willingness to control pig aggression) is not entirely supported. However, there was a significant indirect influence of PERC on WILL through OB. In addition, results revealed a significant, positive relationship between PP and NST. PERC and OB indirectly influenced NST through PP and the regression coefficient of SI on NST was also positive and approaching significance ($p = 0.07$). Spearman correlation matrix among variables used in the structural model can be seen in Appendix A.

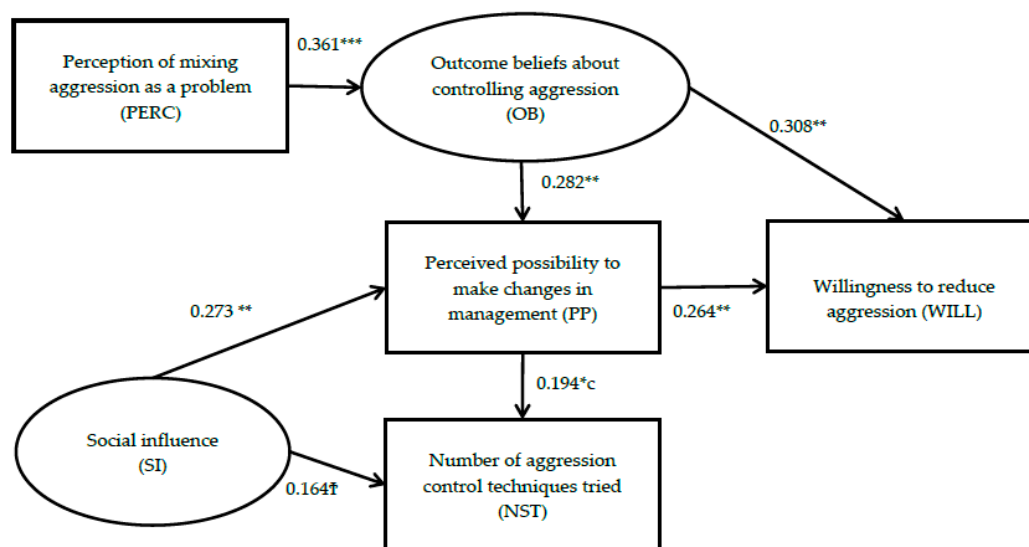


Figure 3. Path diagram of standardized parameters, whereby; [†] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Latent variables are represented by ovals and observed variables by rectangles. All possible relationships between observed and latent variables were estimated and only relationships whereby $p < 0.10$ are displayed. Regression coefficients are presented for each relationship.

5. Discussion

Progress in uptake of advice from animal welfare research largely depends upon the willingness of farmers to adopt changes to farm structure or management. This survey of 122 pig farmers yields new insight into the attitudes and practices found in the UK and Irish pig industries regarding the longstanding animal welfare issue of aggression between pigs. Furthermore, we provide the first investigation into the factors that influence farmer willingness to control aggression. This new insight into farmer decision-making provides tools for bridging the gap between research and practice, which has so far been resistant to change [2].

5.1. Perceptions and Practice Regarding Aggression

All but one participant reported avoiding mixing unfamiliar growing pigs whenever possible. Despite this, the vast majority of farmers mixed growing pigs at least once during production, and for some up to four times. Farmers were aware that aggression is associated with welfare and production costs as the primary motivations for avoiding mixing were concerns over injury/stress for the animals and slowed growth rates. However, only 14.8% of participants perceived that aggression between unfamiliar growing/finishing pigs was a problem on their farm. This finding is consistent with a previous survey showing that the majority of UK pig farmers did not perceive aggression as a problem that needed to be addressed [33]. Nevertheless, 51.6% of surveyed farmers in the current study perceived that aggression is a problem for the industry. Therefore the majority of farmers believe that they sufficiently control aggression at mixing on their farm, and seem unwilling to acknowledge an issue with their own production system or are indeed successfully controlling aggression despite mixing pigs.

Aggression mitigation strategies have been researched since the 1970s. They display mixed efficacy results in empirical trials, reviewed several times [2,7,9,48]. The majority of respondents were aware of aggression mitigation strategies and 88.5% had tried at least one strategy to control aggression at mixing in the past. Farmers found pre-weaning socialization to be more useful than employing mixed-weight pens and mixing pigs from neighboring pens, the latter two being the only strategies that were judged not useful. Farmers perceived all other aggression mitigation strategies as comparably useful.

For some strategies, their perceived usefulness in the current study is consistent with their usefulness in the peer-reviewed literature. Mixing pigs from neighboring pens was proposed to reduce aggression by allowing pigs to become familiar with one another prior to mixing, but its efficacy for reducing aggression has received inconsistent support from a small number of empirical trials [7,49,50] and it was not judged useful in the current study. Pre-weaning socialization is one of the most promising strategies to control aggression identified by research [2] and was judged the most useful strategy in the current study. A recent experiment showed that pre-weaning socialization was beneficial also on a large scale commercial farm [11] and such information is a useful addition to the studies done under research conditions. However, despite its effectiveness, only 38.5% of surveyed farmers had tried it, although uptake was slightly higher than reported in a previous survey of 167 UK pig farmers whereby 27% of farmers with breeding sows employed the strategy [33]. The limited uptake of this strategy may be due to concerns about its practical management including increased work load, pathogen spread, growth and mortality [33]. The perceived usefulness of housing pigs in large social groups is also in agreement with the research, which suggests that pigs adopt a less aggressive social strategy when the costs associated with aggression outweigh the benefits [51,52]. Group size must be sufficiently large (more than 12 individuals) to have an impact on aggression levels [51] but much larger groups (>80 pigs) are more effective [12,52]. Average group size for growing/finishing pigs in the current study exceeded 80, illustrating the move towards larger group sizes observed in industry and driven by reduced cost, ease of management [53] and by the development and launch of automatic sorting technology which requires large groups [54].

The participants' judgment that some strategies were somewhat useful is inconsistent with the research evidence. The most commonly used strategy was distraction using materials/toys, despite there being no evidence supporting its effectiveness. This could be linked to the fact it is relatively cheap and easy to add available materials to pens. Provision of enrichment is a requirement of EU Council Directive 2008/120/EC to control tail biting, but it must be used appropriately in order to avoid an increase in aggression caused by easily defensible resources, i.e., a sufficient number of objects should be present to ensure adequate access [55]. As farmers reported this strategy to be useful in controlling aggression, it is possible that they still considered tail biting as aggression. It may also be that research has largely ignored practical low-cost strategies that have emerged from practice, such as providing roughage at regrouping. Odor masking agents, which disrupt the olfactory processes by which pigs recognize each other, and barriers/get-away areas, which allow pigs to escape, show somewhat mixed results in research [2,7,56]. Moreover, tranquilizers [57] and evening/night-time mixing [58] appear to delay rather than reduce aggression [2,7]. Mixed-weight groups were not judged useful here although they do appear to reduce aggression in empirical trials by allowing dominance hierarchies to be clearly determined by physical size and strength [3]. This lack of correspondence between strategies found to be useful in research and in industry was also observed in a previous study [15] whereby the author suggested that other influences are involved, such as differences in the associated costs and ease of implementation influencing their relative perceived benefits. Indeed, mixed-weight pens restrict access to resources for low weight pigs resulting in increased divergence in weight as pigs grow [7,59]. Having pigs reach slaughter-weight at different times results in less efficient use of space and requires further regrouping of smaller pigs left behind. Therefore, their lack of usefulness could be associated with the fact they are not practical to manage in a commercial setting.

Two farmers used shower sprays/water sprinklers to control aggression at mixing. This is encouraged in the code of recommendations which must be read and understood by all farmers in the UK [60–62] despite no peer reviewed research existing that has investigated the use of this strategy.

5.2. Factors Influencing Farmer Willingness to Implement Aggression Mitigation Strategies

Despite the fact that most farmers had tried at least one aggression mitigation strategy in the past, only 41% of participants indicated willingness to implement aggression control strategies in the near future. Farm location had no impact on farmers' use of aggression control strategies in the past or

their willingness to control aggression in the future; suggesting similar practice between Ireland and counties within the UK. SEM analysis confirmed that a range of interrelated internal and external factors influenced the number of aggression mitigation strategies tried in the past and farmer willingness to implement strategies in the future. Willingness to act in the future was directly influenced by beliefs about the consequences of controlling aggression and whether farmers felt able to implement the change (therefore supporting H1 and H2). The value of relevant stakeholder opinion, and perceiving aggression to be a problem on their farm, did not directly influence farmers' willingness to implement aggression control strategies (therefore not supporting H3 and H4). However, both the value of relevant stakeholder opinion, and perceiving aggression to be a problem on their farm, did indirectly effect willingness through enhancing farmers' perceived possibility to implement strategies and by enhancing beliefs about the beneficial outcomes of controlling aggression, respectively.

Farmers' own perceptions about their ability to make changes in management played a central role in their willingness to implement aggression control strategies. It was directly affected by both outcome beliefs and social influence and, in turn, had a direct effect on both willingness to implement aggression control strategies in the future and the number of strategies tried in the past. This is consistent with previous research whereby farmers' decisions regarding animal welfare were influenced by their beliefs about the presence of factors that may facilitate or impede implementation of a particular change [19,20,23]. Implementation of aggression control strategies could therefore be stimulated by enabling farmers to make changes or by giving them the confidence that change is possible.

Beliefs about the outcomes of controlling aggression were the biggest determinant of farmer willingness to implement aggression mitigation strategies. One solution would therefore be to prove whether research results can be consistently replicated in practice and yield benefits that would outweigh potential costs. This can be achieved by testing strategies under commercial conditions and by conducting cost-benefit analyses. Outcome beliefs were directly limited by the fact that the majority of farmers did not perceive aggression to be a problem on their farm. Therefore, an important target for intervention is providing farmers with the necessary knowledge and tools to accurately recognize when aggression is an issue, for example by encouraging farmers to observe the number and location of lesions which can provide a quick and well established estimate of aggressive behavior and can help farmers to identify the extent of the problem on their farm [63,64]. Farmer beliefs regarding the financial outcomes of controlling aggression are likely to be limited further as the economic consequences of aggression have never been calculated. Uncertainty about price premiums is a major barrier to investment in animal welfare [22,65]; therefore research is required to establish the cost-effectiveness of aggression mitigation strategies in order to predict the outcome of interventions on farm profitability. The SEM analysis reveals that by targeting outcome beliefs, farmers may perceive the possibility to make changes in management as greater.

Relevant stakeholder groups influenced farmers' perceived possibility to make changes in management, highlighting another important target for implementing changes on-farm. Interestingly, stakeholders did not influence the likelihood that farmers would perceive aggression on their farm to be a problem, or their beliefs about the benefits of controlling aggression. This highlights that current methods of communicating with farmers on these specific issues requires improvement. Veterinarians had the greatest influence, which is consistent with the fact that veterinarians are the most obvious point of call for advice regarding harmful issues such as aggression, and they were previously identified by pig farmers as their most trusted and preferred source of information [27]. Researchers, other pig farmers, agricultural advisors and quality assurance bodies all had a lower, but potentially important, influence on farmer behavior regarding aggression. The wholesale/retail trade, consumers, levy bodies and slaughterhouse staff did not drive industry towards change on this matter and this is linked to the fact that pig aggression is either unknown to these groups or not a priority to the majority of these groups, who are known to lack engagement with specific animal welfare issues on the farm (e.g., retailers [66,67]; consumers [65,68,69]; slaughterhouse staff [70,71]). Therefore, researchers should effectively communicate their findings not only to farmers, but to a variety of stakeholder groups,

with special emphasis on veterinarians. To be effective, researchers should tailor their communication based on the knowledge base of their audience and move away from the traditional, unidirectional lecture format [72,73].

Applying SEM provided insight into farmer decisions regarding pig aggression. We had a relatively small sample size for SEM analysis, but comparable to previous published research employing SEM (e.g., [74]; $n = 101$). Recruitment of pig farmers for surveys remains difficult [34] and studies must be carefully designed to avoid bias towards including only proactive farmers. Other factors may have impacted farmers' decisions about animal welfare as well, such as their immediate family and personality characteristics [16]. The SEM approach was powerful for analyzing the direct and indirect links between a multitude of social factors and we recommend applying this method to other important animal welfare challenges.

6. Conclusions

The majority of respondents were aware of aggression mitigation strategies and had tried at least one strategy to control aggression in the past. Strategies were generally thought of as moderately useful but the majority of farmers were reluctant to employ strategies in the near future. Structural equation modeling analysis showed that farmer willingness to make a change was directly influenced by their beliefs about the outcome and their perceived possibility to make a change. Furthermore, their perceptions of the problem and relevant stakeholder groups indirectly influenced willingness to make a change. We recommend that researchers employ a multipronged approach to encourage implementation of control strategies. By testing aggression control strategies outside of the highly controlled research setting it will be possible to establish their outcomes and practical implementation under commercial conditions. By calculating the economic consequences of aggression mitigation it will be possible to advise farmers on the most cost-effective solutions and their impacts on farm profitability. Finally, information on the consequences of aggression, how to recognize it as a problem and how to control the issue must be effectively transferred into industry by researchers. Knowledge transfer should be directed not only at farmers but should be channeled through various sources, with special emphasis on veterinarians. The SEM approach could also be successfully employed to understand other entrenched welfare challenges in livestock production where there is inadequate implementation of mitigation strategies.

Supplementary Materials: The following are available online at https://osf.io/7ceqg/?view_only=0bbcd97785e447a6bcb9c24df3549abf, Survey, Data.

Author Contributions: R.S.E.P. designed the experiment and conducted investigation, statistical analysis of the data, and writing of the original draft manuscript. S.P.T. provided supervision at all stages of the project, conducted investigation, and reviewed, commented and edited the manuscript. F.A. provided supervision, conducted statistical analysis of the data and reviewed, commented and edited the manuscript. I.C. provided supervision at all stages of the project and reviewed, commented and edited the manuscript. L.B. conducted investigation, and reviewed, commented and edited the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Spearman correlation matrix among variables used in the structural model whereby * $p < 0.05$, ** $p < 0.01$.

	OB ₁	OB ₂	OB ₃	SI ₁	SI ₂	SI ₃	SI ₄	SI ₅	SI ₆	SI ₇	SI ₈	SI ₉	PP ₁	PP ₃	PP ₃	PP ₄	NST	PERC	WILL
OB ₁																			
OB ₂	0.853 **																		
OB ₃	0.746 **	0.813 **																	
SI ₁	0.075	0.104	0.121																
SI ₂	0.214 *	0.233 **	0.256 **	0.262 **															
SI ₃	0.092	0.101	0.099	0.239 **	0.601 **														
SI ₄	0.155	0.116	0.161	0.304 **	0.604 **	0.559 **													
SI ₅	0.026	0.046	0.160	0.259 **	0.466 **	0.574 **	0.516 **												
SI ₆	−0.008	0.003	0.062	0.214 *	0.521 **	0.684 **	0.580 **	0.602 **											
SI ₇	0.155	0.074	0.173	0.318 **	0.430 **	0.405 **	0.653 **	0.433 **	0.430 **										
SI ₈	0.016	0.040	0.122	0.289 **	0.527 **	0.513 **	0.645 **	0.496 **	0.662 **	0.477 **									
SI ₉	0.030	0.048	0.056	0.326 **	0.445 **	0.571 **	0.555 **	0.542 **	0.685 **	0.523 *	0.551 **								
PP ₁	0.264 **	0.277 **	0.239 **	0.144	−0.134	−0.121	−0.045	−0.078	−0.210	−0.051	−0.066	−0.009							
PP ₂	0.190 *	0.275	0.349 *	0.069	0.181 *	0.171	0.275 **	0.230 *	0.263 **	0.156	0.295 **	0.196 *	0.230 *						
PP ₃	−0.026	0.18	0.103	0.114	0.029	0.049	0.159	0.096	0.170	0.050	0.210 *	0.079	0.209 *	0.566 **					
PP ₄	0.017	0.000	0.107	0.051	−0.030	0.023	0.032	0.080	0.048	−0.002	0.093	0.128	0.288 **	0.195	0.445 **				
NST	−0.046	−0.028	0.146	0.085	0.119	0.176	0.116	0.249 **	0.154	0.192 *	0.170	0.089	0.125	0.255 **	0.165	0.095			
PERC	0.317 **	0.285 **	0.300 **	−0.033	0.213 *	0.069	0.042	0.103	0.111	0.015	0.094	0.046	−0.142	0.059	−0.199 *	0.042	0.092		
WILL	0.295 **	0.373 **	0.422 **	0.054	0.189 *	0.049	0.161	0.141	0.080	0.239 **	0.143	0.094	0.275 **	0.363 **	0.145	−0.007	0.152	0.125	
Median	5	5	5	6	5	3	4	2	3	5	4	3	6	4.5	4	4	3	3	4

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4. Limitations

A number of limitations of this study's methodology were described in the published article. However, further limitations are acknowledged here. The hypotheses for this study were highly influenced by the Theory of Planned Behaviour (TPB) (see Figure 1). This is due to the hypotheses being formed based on reviewing the literature on farmers' decisions regarding animal welfare; and the TPB has dominated this literature (Carroll and Groarke, 2019). However, the TPB fails to account for moral norms, motivation, culture and social and economic constraints (Carroll and Groarke, 2019). Pig welfare issues cannot be separated from market forces, government regulations, farm size and structure, and changing consumer demands. Therefore, a central limitation of this study is that it does not account for all of the components of farmers' context which are likely to influence their behaviour regarding aggression. Future research into the development of suitable interventions to encourage uptake of animal welfare research in practice may benefit from recent developments in the field of human behaviour change. The Behaviour Change Wheel (BCW) provides a structured approach to designing interventions which will change specified human behaviours; and it overcomes the weaknesses of more traditional models of behaviour by

accounting for the social, political and economic context of the behaviour (Michie et al., 2011; Carroll and Groarke, 2019).

It has been well established in consumer science that an attitude-behaviour gap exists, whereby participants' behaviour may not be consistent with their stated attitudes and intentions (Carrington et al., 2010). It is possible that farmers' in the current study answered in a way that they deemed favourable to others, rather than how they actually felt. Therefore, farmers' may have over-stated their willingness to implement aggression controls strategies.

5. Conclusions

Many interrelated internal and external factors influence farmers' behaviour regarding animal welfare (e.g., (Hemsworth et al., 1994; Willock et al., 1999; Coleman et al., 2000; Hemsworth, 2003; Alarcon et al., 2014). This chapter established the current practice of UK and Irish pig farmers with regards to aggression between pigs and identified the factors that influence farmers' willingness to reduce aggression. The vast majority of surveyed UK and Irish pig farmers mixed growing pigs at

least once during production. Most farmers (88.5%) had tried at least one strategy to control aggression at mixing in the past. However, only 41% of participants were willing to implement strategies again in the future.

Willingness was influenced by: 1) whether farmers felt able to implement the change, 2) beliefs about the likely consequences, 3) perceptions of aggression as a problem on their farm, and 4) the opinion of relevant stakeholder groups. The opinion of veterinarians was particularly significant, thus supporting the findings of (Brennan et al., 2016; Richens et al., 2018). This chapter makes important recommendations on how to bridge the gap between research and practice. Specifically, practical and economically viable solutions should be identified and farmers should be provided with the information required to successfully implement them. The consequences of implementing strategies should be demonstrated by testing them under commercial conditions, and by conducting cost-benefit analyses to establish their financial implications (see Chapter 7). Furthermore, farmers could benefit from information on the consequences of aggression, and how to recognize it as a problem. Knowledge transfer should be directed not only at farmers but should be channelled through various sources, with special emphasis on veterinarians. In the next chapter I take the first steps in addressing these recommendations, specifically regarding the identification of practical

and economically viable solutions by identifying the bounds of management change possible for farmers.

Supplementary materials: The survey can be found in Appendix E.

Chapter 6: Pig farmers' willingness to pay for management strategies to reduce aggression between pigs

1. Introduction

In the previous chapter I established that farmers' willingness to implement aggression control strategies is influenced by a range of interrelated internal and external factors. Specifically: 1) the farmers' perception of their own ability to make the necessary management changes, 2) their beliefs about the likely outcomes, 3) their perception of aggression as a problem, and 4) their views of relevant stakeholder groups. As a result of these findings, several important recommendations were made. This chapter takes the first steps in addressing one of these recommendations; specifically regarding the identification of practical and economically viable solutions. This chapter provides the first investigation into farmers' willingness to pay for aggression control strategies through an economic choice experiment. By identifying the bounds of management change possible for farmers, it is ultimately possible to identify solutions which are compatible with these constraints in Chapter 7. This chapter consists of a published peer-reviewed journal article (Section 2). Furthermore, I include a discussion of data which was not included in the publication but is of importance to this thesis (Section 3), discuss the results in their wider context (Section 4) and end with concluding remarks (Section 5).

2. Journal article

Declaration

Rachel Peden designed this study, collected data, analysed data and wrote the original version of the manuscript. Simon Turner and Laura Boyle helped to collect data at farmer discussion groups. Faical Akaichi explained and demonstrated how to design the study and analyse the data. Rachel Peden conducted the statistical analyses included in the final paper. Faical Akaichi, Irene Camerlink, Simon Turner and Laura Boyle all provided feedback and advice on drafts of the manuscript. They did not directly edit the manuscript but provided comments and recommendations using the 'review' function in Microsoft Word. Rachel Peden either refuted or made the relevant corrections. Furthermore, Rachel Peden revised the manuscript in response to external peer review comments, prepared the response letter for the journal and was the corresponding author. Inclusion of this publication complies with copyright laws. Permission from co-authors was obtained regarding the inclusion of this article in the current thesis.

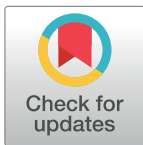
RESEARCH ARTICLE

Pig farmers' willingness to pay for management strategies to reduce aggression between pigs

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Abstract

When deciding whether to invest in an improvement to animal welfare, farmers must trade-off the relative costs and benefits. Despite the existence of effective solutions to many animal welfare issues, farmers' willingness to pay for them is largely unknown. This study modelled pig farmers' decisions to improve animal welfare using a discrete choice experiment focused on alleviating aggression between growing/finishing pigs at regrouping. Eighty-two UK and Irish pig farm owners and managers were asked to choose between hypothetical aggression control strategies described in terms of four attributes; installation cost, on-going cost, impact on skin lesions from aggression and impact on growth rate. If they did not like any of the strategies they could opt to keep their current farm practice. Systematic variations in product attributes allowed farmers' preferences and willingness to pay to be estimated and latent class modelling accounted for heterogeneity in responses. The overall willingness to pay to reduce lesions was low at £0.06 per pig place (installation cost) and £0.01 per pig produced (running cost) for each 1% reduction in lesions. Results revealed three independent classes of farmers. Farmers in Class 1 were unlikely to regroup unfamiliar growing/finishing pigs, and thus were unwilling to adopt measures to reduce aggression at regrouping. Farmers in Classes 2 and 3 were willing to adopt measures providing certain pre-conditions were met. Farmers in Class 2 were motivated mainly by business goals, whilst farmers in Class 3 were motivated by both business and animal welfare goals, and were willing to pay the most to reduce aggression; £0.11 per pig place and £0.03 per pig produced for each 1% reduction in lesions. Farmers should not be considered a homogeneous group regarding the adoption of animal welfare innovations. Instead, campaigns should be targeted at sub-groups according to their independent preferences and willingness to pay.

Competing interests: The authors have declared that no competing interests exist.

Introduction

Several animal welfare issues persist in agriculture despite solutions being identified by extensive research (e.g. [1, 2]). Farm animals are business capital whose value is in direct proportion to their productivity, and although ensuring certain animal welfare standards is necessary to sustain productivity (e.g. feed, housing, disease control, environmental management), providing some improvements to animal welfare can be more expensive than the returns gained [3–5]. Therefore, it can be cheaper for farmers to accept losses due to certain welfare threats than to prevent these losses and, when deciding whether or not to invest in an animal welfare innovation, farmers must estimate and then trade-off the relative costs and benefits of making the change. Farmers are generally risk adverse, and in order to make an investment in animal welfare they must be confident that the costs will be covered by returns in productivity [6–12]. Nevertheless, farmers cannot be considered a homogeneous group. Their businesses differ in size, structure, location and management practices, farmers differ in personal attitudes and perceptions, and all of these factors can influence decisions with regards to animal welfare [9, 13–15]. Therefore, it is likely that farmers' preferences and willingness to pay for animal welfare improvements are also heterogeneous. Although willingness to pay and its heterogeneity within a farming population are key determinants of whether effort will be made to improve animal welfare, these have rarely been estimated. This contrasts with the considerable research effort on identifying and refining management innovations to improve animal welfare. There is a need to bridge the gap between research and practice to facilitate the uptake of welfare solutions that fit within farmers' willingness to pay constraints. Therefore it is crucial to: 1) understand how farmers make business decisions regarding specific animal welfare issues, and 2) account for heterogeneity in their preferences. In doing so, subgroups of farmers likely to invest in animal welfare can be identified, and campaigns to bridge the gap between research and practice can be targeted more effectively at farmers.

Aggression between pigs is one example of an animal welfare issue which has received extensive research, but seen inadequate progress in commercial practice [2]. Aggression occurs primarily when unfamiliar pigs are regrouped, as this disrupts their dominance hierarchy and they fight in order to re-establish dominance relationships [16]. Two surveys of 167 and 122 UK and Irish pig farmers found that farmers regroup unfamiliar pigs up to four times during each production cycle in order to maximise use of space, and in an attempt to create groups of equal body size which market simultaneously [17, 18]. Aggression threatens pig productivity as animals become more susceptible to infection due to the transient effects of stress upon the immune system [19], they acquire skin injuries as a result of bites [16, 20], and they are more likely to display lameness [21], slowed growth rates [22, 23] and reduced meat quality [24]. Several strategies to reduce the occurrence or intensity of aggression at regrouping have been identified, requiring farmers to make specific changes to animal management, nutrition or genetics (review articles: [25–27]). Some promising developments for use with growing/finishing pigs include housing pigs in relatively large social groups [28, 29], providing sufficient space at regrouping [30, 31], and providing a diet high in the amino acid tryptophan [32, 33]. Strategies are associated with monetary costs, and the extent and nature of these costs vary between strategies and between farms. Initial investment costs rely on business capital, and may result from the purchasing and fitting of new materials, or the restructuring or building of accommodation. Running costs may result from increased labour requirements and the replenishment of materials, and therefore mainly affect variable costs. Implementation of a strategy in practice may require only investment costs, only running costs, or a combination of both.

A recent survey found that although 88.5% of 122 UK and Irish pig farmers had tried an aggression control strategy in the past, only 41% expressed willingness to implement strategies again in the future [17]. Farmers' willingness to implement strategies was influenced by a range of interrelated internal and external factors. Specifically these were: 1) their perception of their own ability to make the necessary management changes, 2) their beliefs about the likely outcomes, 3) their perception of aggression as a problem, and 4) their views of relevant stakeholder groups. Therefore, the limited uptake of aggression research in practice is linked to multiple factors. One of these is a potential misalignment between research and industry interests resulting in impractical or unaffordable solutions [17, 25]. No research to date has provided quantitative information on how farmers' trade-off the relative costs and benefits of aggression control strategies when making investment decisions. Therefore, it is currently unknown whether any aggression control strategies result in benefits which are perceived to outweigh their associated costs. To encourage uptake of welfare solutions it is essential to better align research objectives with industry interests by identifying economically viable solutions based on farmers' demands.

This research examines for the first time farmers' preferences and willingness to pay (WTP) for reductions in aggression through a discrete choice experiment (DCE), and importantly, heterogeneity in farmer preferences is accounted for. DCEs are regularly used in a variety of research areas such as environmental valuation [34], transport systems [35], marketing [36] and healthcare economics [37, 38], and are generally accepted as a valid method for preference elicitation. DCEs are typically implemented in surveys and respondents are asked to indicate their preferred option among a number of different hypothetical alternatives with assigned prices. Preferences are measured via systematic variations of product characteristics ('attributes') in an experimental design. Based on respondent choices it is possible to estimate the relative importance of the different attributes [39, 40]. DCEs can also be used to estimate WTP for both changes in individual attributes, and changes in any combination of attributes [37, 38]. Furthermore, heterogeneity in these preferences can be understood by employing latent class modelling (LCM) [41] which identifies different classes of respondents based on both their demographic characteristics, attitudes and their preferences.

Specifically, this study aimed: 1) to measure farmers' preferences for animal welfare improvements (i.e. reduction in lesions) and business goals (i.e. improvement in growth rate) when deciding to invest in an aggression control strategy, 2) to estimate farmers' WTP for reductions in lesions and improvements in growth rate, and 3) to evaluate heterogeneity in their preferences and WTP. By identifying which attributes of aggression control strategies are attractive and important to farmers, and how they trade-off different costs and benefits, it may be possible to identify economically viable solutions that are compatible with these constraints. Furthermore, future research can be directed towards identifying new solutions which meet farmers' demands. Crucially, by accounting for heterogeneity in these preferences, campaigns can be tailored and targeted at farmer subgroups according to their preferences and characteristics.

Methods

Experimental design

Farmers completed a paper based survey consisting of two sections. The first involved a choice task. Then, they were required to complete a questionnaire about their attitudes, farm characteristics and socio-demographic characteristics. Although previous research has successfully conducted choice experiments electronically, we chose to recruit participants face-to-face with a paper-based survey in order to maintain quality of responses and due to poor response rates

of farmers to previous online surveys [17, 42]. Details of the sample size and recruitment process are given below in the section titled 'Data collection'.

The choice task. In the choice task, farmers were asked to choose between four options. These options consisted of three hypothetical aggression control strategies (named simply as 'strategy 1' to 'strategy 3') which would be employed when regrouping unfamiliar growing/finishing pigs on their farm. As the use of aggression control strategies in practice is optional, it would be unrealistic to force farmers to choose a strategy. Therefore, we also included a status quo option to allow farmers to keep their current practice with regards to aggression and make no additional investment; hence mimicking the real life situation. Although pigs are more commonly mixed at weaning than at growing/ finishing [17, 18], the choice task focussed only on the growing and finishing stages of production. This is because farmers perceive aggression as a greater problem at growing/finishing compared to at weaning, and would be more likely to adopt a solution for these pigs [18]. Furthermore, at weaning, regrouping aggression has less impact on growth performance and less risk of lameness and injuries than at the grower/finisher stage when pigs are heavier and stronger [43]. Each alternative aggression control strategy was described in terms of four attributes: 1) One-off investment cost for installation of equipment or materials. As this cost would last for many production cycles, it was described 'per pig place'; 2) Running cost associated with the running and management of the investment. As this cost would be required for every production cycle, it was described 'per pig produced'; 3) Percentage reduction in lesions in the seven days following mixing (indicating a reduction in aggression [20]) and; 4) Percentage improvement in growth rate in the seven days following mixing achieved at the same level of food intake. Attributes 1 and 2 were expressed in Great British Pound Sterling and attributes 3 and 4 represented the change in lesions or growth rate relative to the farmer's current practice. The levels for attributes 1 and 2 were assigned based on reviewing industry websites for products and relevant materials. The levels for attributes 3 and 4 were assigned based on the range found in the academic literature [16, 44–47]. Each attribute level was assigned an attribute level code as is required to design the level combinations (or 'choice sets', described below). See Table 1 for levels of each attribute and their associated codes.

Table 1. Attributes, attribute levels and attribute level codes for the hypothetical aggression control strategies.

Attribute	Attribute level	Attribute level code
One-off investment cost per pig place (£)	£1.22 per pig place	0
	£3.62 per pig place	1
	£6.12 per pig place	2
	£9.12 per pig place	3
Running cost per pig produced (£)	£0.12 per pig produced	0
	£0.24 per pig produced	1
	£0.34 per pig produced	2
	£0.46 per pig produced	3
Reduction in lesions (%)	10% reduction	0
	20% reduction	1
	30% reduction	2
	40% reduction	3
Improvement in growth rate (%)	0%	0
	2%	1
	5%	2
	8%	3

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Given all the attribute levels, a full factorial design of 256 (i.e. $4 \times 4 \times 4 \times 4$) was created. Presenting the participants with 256 choices would be too time-consuming and demanding. Therefore, an optimal fractional factorial design was generated and used instead, whereby only a subset of the level combinations (or 'choice sets') appeared (see Table 2 for an example of a choice set). We followed the approach proposed by Street and Burgess (2007) [48] to generate an orthogonal design using the statistical software SPSS v17. A design is orthogonal if each attribute level appears an equal number of times, and the effects of each attribute on the participants' responses can be independently estimated. The size of the orthogonal design (in this case 16 combinations) is equal to the minimum number of combinations required to meet these requirements. Prior research indicates that participants are able to complete 17 choice sets without problem [49]; therefore we saw 16 as a realistic number of choices for farmers to complete. These 16 combinations of the four attributes were used as the first aggression control strategy in each of the 16 choice sets (the 'starting design'). Since participants were provided with choice sets of three aggression control strategies each plus a status quo option, the second and the third aggression control strategies were obtained using the generators (1111) and (2222), respectively. Generators were applied to the attribute level codes (see Table 1) to shift the levels of the attributes. See Street and Burgess (2007) for more details on how to obtain the generators and use them to generate the remaining options in a choice set.

After generating all of the choice sets, each one of them was examined for implausible attribute combinations (e.g. where both investment and on-going costs were £0.00 but benefits to aggression and/or growth were positive), and attribute combinations that were clearly dominant (e.g. minimal costs and maximum benefits). These were removed to ensure a valid estimation process and to facilitate the perceived credibility of the tasks among the respondents, and the fractional factorial design was re-generated. Efficiency is a measure of the level of precision in which effects are estimated [34] and the final design had 100% statistical efficiency.

Hypothetical bias refers to bias caused when stated hypothetical WTP is higher than the real WTP, and is a major challenge for stated preference methods [50, 51]. To minimise the effect of hypothetical bias, first, a 'cheap talk' script was included to explicitly encourage participants to reveal their true preferences by answering exactly as they would if they had to choose an aggression control strategy for their farm, and had to pay for their choice. Second, an 'opt-out reminder' was used prior to each choice set. The opt-out reminder stated: 'please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'status quo' option'. Hypothetical bias has been reduced by employing cheap talk scripts [51–53] and opt-out reminders [50] in prior research. Order effects were minimised by printing the choice sets in a different order for every respondent.

Attitudes, farm characteristics and socio-demographic characteristics. After successfully completing the choice task, farmers who chose the 'status quo' for all the choice sets were asked to indicate why by ticking all relevant options from: 'I would not adopt any of the aggression control strategies on my farm', 'I already use aggression control strategies on my farm', 'I don't mix unfamiliar growers/ finishers', 'I didn't read the other options', 'I wanted to get finished quickly', and 'Other. . . please state. . .'. All farmers were then asked to indicate their level of agreement/ disagreement (from 1 = strongly disagree to 5 = strongly agree) with seven attitudinal statements, specifically; 1) 'when mixing unfamiliar pigs, minimizing aggression is important to me', 2) 'mixing aggression is a problem on my farm', 3) 'I avoid mixing unfamiliar pigs wherever possible', 4) 'it is possible to control aggression at mixing', 5) 'UK standards of pig welfare are sufficiently strict', 6) 'the welfare of my animals is important to me', 7) 'the welfare of my animals is good'. All farmers were also asked to indicate their use of the following eight aggression control strategies when mixing unfamiliar growing/finishing pigs on their farm by circling either 'currently use', 'used in the past' or 'never used': 1) 'large

Table 2. An example of a choice set presented to farmers.

Attributes	Unnamed strategy 1	Unnamed strategy 2	Unnamed strategy 3	Status quo
One-off investment cost per pig place (£)	£6.12	£9.12	£1.22	£0.00
Running cost per pig produced (£)	£0.34	£0.46	£0.12	£0.00
Reduction in lesions (%) during 7 days after mixing	10%	20%	30%	0%
Improvement in growth rate (%) during 7 days after mixing	5%	8%	0%	0%

Please mark the option you are most likely to adopt

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social group sizes', 2) 'increased space allowance', 3) 'adding extra tryptophan to the feed', 4) 'solid visual barriers/ escape areas', 5) 'mixed weight groups', 6) 'mixing at night/ low light levels', 7) 'novel enrichment material', and 8) 'tranquilisers (e.g. azaperone)'. Farm information was collected regarding location, quality assurance scheme membership, farm size (number of pigs), housing system (indoor/outdoor/combined), average group size, and at what stages of production pigs are mixed. Personal demographic information was collected regarding gender and years of experience working with pigs. The full survey is available in supplementary materials 'S1 Survey'.

The full study was piloted with two farmers and four researchers in order to test understanding of the choice contexts, attributes and their levels, to establish the time taken to complete the survey, and to check the appropriateness and wording of the questions. The survey was amended according to the feedback received and the final version of the survey received ethical approval from the Human Ethical Review Committee at the University of Edinburgh. Informed consent was obtained from all participants.

Data collection

A total of 114 commercial pig farmers either completed or partially completed the survey between November 2017 and January 2019. The target population was UK and Irish pig farmers who kept pigs at the growing and/or finishing stages of production, and were responsible for making financial decisions on their farm (farm owners and managers). Farmers were recruited at nine farmer discussion groups ($n = 102$), at the Pig and Poultry Fair 2018 ($n = 3$) and by one colleague employed by the Agricultural and Horticultural Development Board (AHDB) Pork while on farm visits ($n = 9$). Farmer discussion groups are organised, usually quarterly, in each of the pig producing regions of the UK and each attended by between 10 and 40 farmers. Discussion groups held in Ireland are often smaller (5–15 farmers) and likely to meet more frequently. The focus of the meetings is to improve technical efficiency and profitability and they are attended by farmers from across the spectrum of the industry regarding herd size and methods of production. Animal welfare topics are not usually discussed at these meetings, and farmers were unaware that they would be asked to participate in animal welfare research prior to attending. Therefore, they were not self-selected with regards to specific welfare views, which is a risk when recruiting farmers through postal or telephone surveys. However, there is a risk that these farmers were more progressive than the population in general. Farmers recruited while on farm visits were unaware that they would be asked to participate in animal welfare research during the visit, and thus were not self-selected based on specific welfare views. Furthermore, these farmers were unlikely to be more progressive than the population in general.

Prior to participation all farmers were presented with standardised instructions providing information on the context of the study, the definition of the four attributes, how to interpret and complete the choice sets, and the 'cheap talk' script. Farmers were also asked not to talk to

each other whilst filling in the survey. For participants recruited at discussion groups these instructions were presented in a PowerPoint presentation, whilst those who participated elsewhere were provided the same instructions in a paper document which the experimenter read to them before completing the survey. Participants were given the opportunity to ask questions following the instructions, prior to completing the survey.

Socio-demographics of the final sample. In order to analyse the choice data, it was necessary for farmers to complete all 16 choice sets. Two farmers only partially completed the choice sets and were eliminated from analysis. A further two farmers were eliminated because they did not keep growing or finishing pigs, and one was eliminated due to reporting their farm as located in the USA. Furthermore, responses from farm workers ($n = 16$), contract farmers ($n = 2$), retired farmers ($n = 4$) and those employed in 'other' roles were eliminated from analysis as these individuals had no responsibility for making financial decisions on their farm. 'Other' roles were advisors ($n = 3$), a production manager ($n = 1$) and an employee of the pesticide industry ($n = 1$).

Of the final 82 participants, 72% were farm owners and 28% were managers, and they had on average 29.7 years of experience working with pigs (std 13.5, range 4–60 yr). The majority were male (79.3% male; 12.2% female; 8.5% undisclosed), and this is consistent with the majority of agricultural workers being male in the UK and Republic of Ireland [54]. Respondents were based in England (69.5%) and the Republic of Ireland (30.5%). Although the majority of the UK pig industry is based in England (>80%), a minority is based elsewhere in Scotland, Northern Ireland and Wales [55]. Therefore the UK sample cannot be considered fully representative of the UK pig industry. All of the Irish farmers ($n = 25$) were assured by Bord Bia. The majority of English farmers were assured by Red Tractor (78.9%), followed by Assured British Pigs (12.3%), RSPCA (7%), and Genesis Quality (1.8%). A further 12.3% of English farmers reported having no quality assurance scheme, whilst 3.5% indicated that they were assured by another scheme (ticked 'other') and one farmer specified that they were assured by Marks & Spencer. Some farms were assured by more than one scheme. The proportion of farmers involved in Quality Assurance schemes in the current study is consistent with the industry whereby the majority of farmers are assured by basic schemes, such as Bord Bia and Red Tractor, which meet the minimum requirements of national legislation; but a minority meet higher than minimum standards (e.g. RSPCA) [9, 56–59]. See Table 3 for information on farm size. The majority of growing and finishing pigs were housed indoors (growers: indoors 85.4%, outdoors 0%, combined 2.4%, unspecified 12.2%; finishers: indoors 81.7%, outdoors 0%, combined 2.4%, unspecified 15.9%). Seventy-two farmers reported their average group size for growing pigs, and on average they kept pigs in groups of 47 (std 31.6, range 14–200). Sixty-nine farmers reported average group size for finishers, and they kept pigs in groups of 38 on average (std 45.3, range 12–240). Therefore the majority of pigs were housed indoors and assured by basic quality assurance schemes; furthermore farm size and structure varied widely. This is generally consistent with the structure of the industry in the UK and Republic of Ireland [55, 60].

Discrete choice experiment modelling

All the estimations were conducted using RStudio software (Package "gmnl"). Utility refers to the net benefit from taking an action. In this choice experiment, the farmer assigned some utility to each management intervention in the choice set, and chose the one with the greatest utility. According to Lancaster (1966), any product, or in this case management intervention, is a bundle of attributes, and utilities are derived from the bundle of attributes rather than from the intervention as a whole [61]. Following this concept, what a farmer derives from an

Table 3. Mean, standard deviation (std), minimum and maximum number of pigs kept at each stage of production (number of farmers to answer).

Stage of production (n)	Mean	Std	Minimum	Maximum
Weaners (64)	1904	2170.6	15	10000
Growers (52)	1647	2049.4	15	10000
Finishers (62)	2548	2647.5	0	12000
Sows (63)	598	520.6	50	2184

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intervention is assumed to be equal to the sum of the marginal utilities for each of its attributes. Consequently, individual i 's assigned utility (U_{ijt}) which is specific for each j^{th} intervention alternative a t^{th} choice occasion takes the form:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} \quad (1)$$

V_{ijt} captures the deterministic component (which refers to the utility that the researcher captures) and ε_{ijt} the random component (which refers to all of the things that affect utility that have not been included in V_{ijt}). ε_{ijt} is assumed to be independent and identically distributed for all options in each choice set. Assuming that the deterministic component is linear-in-parameter, the Eq (1) can be written as:

$$U_{ijt} = \beta X_{ijt} + \varepsilon_{ijt} \quad (2)$$

Where β denotes the $K \times 1$ vector of unknown marginal utilities that are associated with the product attributes X_{ijt} . In this study, X_{ijt} represents the following attributes "Installation cost" (IC), "Running cost" (RC), "Reduction in lesions" (RL) and "Improvement in growth rate" (IGR) which were coded as continuous variables using their original values. A fifth variable "None" (NONE) was also considered to estimate respondents' preferences for the status-quo option.

The conditional logit (CL) model [62] is the most commonly used statistical model for analyzing discrete choice data. However, it assumes that respondents' preferences are homogeneous and that alternatives included in any choice set are treated by respondents as independent. Furthermore, it assumes that all choices are independent even if they are made by the same individual and, therefore, likely exhibit some degree of correlation (i.e. in this case each farmer made 16 choices). These assumptions were found to be unrealistic and were not generally met by [63]. Revelt and Train (1998) proposed the Random Parameter Logit (RPL) model, which is less restrictive and relaxes these assumptions [64]. In the RPL model, heterogeneity of the population is taken into account as the parameters are assumed to vary from one individual to another, as is reflected in the individual-specific coefficient β_i . The probability that individual i chooses an alternative j from a particular choice set J at a choice occasion t is specified as:

$$L_{nit}(\beta_n) = \frac{\exp(\beta'_n X_{nit})}{\sum_{j=1}^J \exp(\beta'_n X_{njt})} \quad (3)$$

This probability for individual i is conditional on the direction and magnitude of β_i . Since each farmer was shown a sequence of 16 choice sets, we had multiple observations for the same individual ('panel data'). We took account of this panel dimension by computing one probability for each individual, and this was the probability included in the log-likelihood

function. The choice probability of the observed sequence of choices (S) is given by:

$$S_n(\beta_n) = \prod_{t=1}^T L_{ni(n,t)}(\beta_n) \quad (4)$$

where $i(n,t)$ is the alternative chosen by individual n on choice occasion t .

The unconditional choice probability is the expected value of the logit probability integrated over all possible values of β and weighted by the direction and magnitude of β :

$$P_n(\Omega) = \int_{\beta} S_n(\beta) f(\beta|\Omega) d\beta \quad (5)$$

The expression in (5) does not have a closed form solution; therefore it is approximated through simulation methods. In particular, R draws of β_{ir} are taken from the distribution $f(\beta|\Omega)$. For each draw, the choice probability is calculated. Then the resulting probabilities from the R draws are averaged. We used Modified Latin Hypercube Sampling draws with 1200 simulations. The simulated log-likelihood (SLL) for all respondents, which is estimated via maximum likelihood procedures, is calculated as:

$$SLL = \sum_{n=1}^N \ln \left(\frac{1}{R} \sum_{r=1}^R S_n(\beta^r) \right) \quad (6)$$

In this study, all the parameters were assumed to be normally distributed. The results from the estimation of the RPL model showed that respondents' preferences were highly heterogeneous. While the RPL model controls and accounts for heterogeneity, it does not explain the source of heterogeneity. Greene and Hensher (2003) proposed a latent class model (LCM) for discrete choice analysis that is less flexible than the RPL (i.e. it assumes that the distribution of respondents' attitudes is discrete and not continuous) but it helps identify the sources of the heterogeneity. This is achieved by assuming that respondents belong to different classes, and that their attitudes are homogeneous within each class but are heterogeneous across classes. Therefore, the LCM for discrete choice analysis allows the class that a respondent belongs to be related to their characteristics and their observed behaviour (i.e. their choices of preferred combinations of attributes). In the case of LCM for discrete choice analysis, the log likelihood for all respondents is:

$$\ln L = \sum_{i=1}^N \ln \left[\sum_{q=1}^Q H_{iq} \left(\prod_{t=1}^{T_i} P_{it|q}(j) \right) \right] \quad (7)$$

Where H_{iq} denotes the prior probability for class q for individual i . For this study, the form of the prior probability is a multinomial logit:

$$H_{iq} = \frac{\exp(z_i' \theta_q)}{\sum_{q=1}^Q \exp(z_i' \theta_q)}, \quad q = 1, \dots, Q, \theta_Q = 0 \quad (8)$$

Where z_i denotes a set of observable characteristics which enter the model for class membership.

$P_{it|q}$ is the choice probability that individual i , conditional to belonging to class q ($q = 1, \dots, Q$), chooses alternative j from a particular choice set J , comprised of j alternatives, in a

particular choice occasion t , and is represented as:

$$P_{it|q}(j) = \frac{\exp(x'_{it,j}\beta_q)}{\sum_{j=1}^J \exp(x'_{it,j}\beta_q)} \quad (9)$$

β_q, θ_q are the parameters to be estimated.

To determine the number of classes, the Consistent Akaike Information Criterion (CAIC), and the Bayesian Information Criterion (BIC) were used. Their computation and values corresponding to LCM with 2 to 5 classes are displayed in Table 4. In the following results section we report the results from the estimation of LCM with 3 classes because this model resulted in the lowest CAIC and BIC values (Table 4). CAIC was employed instead of Akaike Information Criterion (AIC) because, similar to BIC, CAIC punishes the sample size in addition to the number of parameters.

Choice data are often used to estimate the trade-offs that respondents make between attributes, or their marginal rate of substitution. When the cost is included as the denominator in the trade-off calculations, marginal willingness to pay (WTP) can be estimated. WTP is commonly expressed as the negative ratio of the non-price attribute coefficient (e.g. reduction in lesions and improvement in growth rate) to the price (cost) coefficient (e.g. installation cost, running cost):

$$WTP_{non-price\ attribute} = - \frac{\beta_{non\ price\ attribute}}{\beta_{price}} \quad (10)$$

In this study, the attributes were all coded as continuous; therefore, the calculated value represents respondents' WTP for a one unit (1%) increase of the continuous attribute. For example, respondents' WTP for a reduction in lesions with respect to installation cost is calculated as $(-1) \times (\text{estimated coefficient for reduction in lesions} / \text{estimated coefficient for installation cost})$. The obtained value represents the maximum amount of installation cost that a farmer is willing to pay (or invest) to decrease lesions by 1%.

After classifying respondents in 3 classes, we characterized each class using information on respondents' attitudes and socio-demographic characteristics. The explicative variables used in the classes' characterization are described in Table 5. Those variables were regressed against respondent's probability to belong to each of the three classes, which is an output of the latent class model. Since the dependent variable is in the form of a probability, we estimated a Beta regression model for each segment.

Results

Attitudes and current practice regarding aggression

The majority of respondents reported that they avoid mixing unfamiliar pigs wherever possible (Table 6). Nevertheless only 6.4% of farmers reported never mixing unfamiliar pigs during production; 26.9% of farmers regularly mixed once during each production cycle, 38.5% mixed twice, 19.2% mixed three times, 7.7% mixed four times and one farmer mixed five times. Fattening pigs intended for slaughter were most commonly mixed at weaning (80.8%), followed by entry to the grower (25.6%) and finisher (24.4%) stages and at slaughter (16.7%). Despite the frequency of mixing, only 9.3% of farmers' perceived aggression to be a problem on their farm (see Table 6 for results of farmers' agreement/disagreement with each attitudinal statement). Seventy-eight percent of farmers reported that they 'currently use' at least one strategy to reduce aggression when they regroup unfamiliar growing/ finishing pigs on their farm. The most popular strategy was increased space allowance, followed by novel enrichment

Table 4. Information on the latent class model (LCM) model and a random parameters logit (RPL) model. The model with the lowest CAIC and BIC values is the best fit.

Number of Classes	Log likelihood at convergence (LL)	Number of parameters (P)	Number of observations (N)	CAIC	BIC
2	-797.491	17	57	1680.714	1663.714
3	-713.450	29	57	1573.148	1544.148
4	-700.589	41	57	1607.943	1566.943
5	-677.566	53	57	1622.414	1569.414
RPL model	-1066.600	10	82	2187.387	2177.387

CAIC (Consistent Akaike Information Criterion) is calculated using: $-2 * LL + (\ln(N) + 1) * P$

BIC (Bayesian Information Criterion) is calculated using: $-2 * LL + \ln(N) * P$

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material and large social group sizes (see Table 7 for results of farmers' use of aggression control strategies). Farmers who indicated that they employ large social groups sizes to control aggression on average kept growing pigs in groups of 48 (std = 24.8, range 16–130) and finishing pigs in groups of 38 (std = 37.5, range 12–200). Respondents were somewhat divided regarding their level of agreement with the statement 'UK standards of pig welfare are sufficiently strict' (see Table 6), and the majority of farmers who disagreed with this statement were based in England (n = 10), whilst two were based in Ireland.

Table 5. Description of the variables used in the Beta regression.

Variables	Description
Mixing	Coded as 1 if the respondent mixed their pigs at the growing and / or finishing stages of production, and 0 if they did not mix pigs at either of these stages.
Small_size	Coded as 1 if the respondent owned and/or managed a small-size farm (lower quartile of dataset; 1475 or fewer growing / finishing pigs); 0 otherwise.
Medium_size	Coded as 1 if respondent owned and/or managed a medium-size farm (interquartile range of dataset; number of growing / finishing pigs between 1475–4999); 0 otherwise.
Large_size	Coded as 1 if respondent owned and/or managed a large-size farm (upper quartile of dataset; number of growing / finishing pigs 5000 or more); 0 otherwise.
Low_experience	Coded as 1 if respondent had little experience working with pigs (lower quartile of dataset; 20 or fewer years' experience); 0 otherwise.
Medium_experience	Coded as 1 if respondent had medium experience working with pigs (interquartile range of dataset, between 21–39 years); 0 otherwise.
High_experience	Coded as 1 if respondent had much experience working with pigs (upper quartile of dataset; greater than 40 years); 0 otherwise.
Location	Coded as 1 if respondent lived in England; 0 otherwise.
Minimise_agg	Coded as 1 if respondent agreed or strongly agreed with the statement "When mixing unfamiliar pigs, minimizing aggression is important to me"; 0 otherwise.
Problem_farm	Coded as 1 if respondent agreed or strongly agreed with the statement "Mixing aggression is a problem on my farm"; 0 otherwise.
Poss_control	Coded as 1 if respondent agreed or strongly agreed with the statement "It is possible to control aggression at mixing"; 0 otherwise.
UK_standards	Coded as 1 if respondent agreed or strongly agreed with the statement "UK standards for pig welfare are sufficiently strict"; 0 otherwise.
Welfare_important	Coded as 1 if respondent agreed or strongly agreed with the statement "The welfare of my animals is important to me"; 0 otherwise.

The variables "Small_size" and "Medium_experience" and two attitudinal statements ("I avoid mixing unfamiliar pigs wherever possible" and "the welfare of my animals is good") were not included in the analysis to avoid the problem of multi-collinearity.

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Table 6. Median agreement (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) with each attitudinal statement, and the percentage (number) of farmers to agree or strongly agree, and disagree or strongly disagree with each statement.

Attitudinal statement (n respondents)	Median response	% agree (n)	% disagree (n)
When mixing unfamiliar pigs, minimizing aggression is important to me (75)	5	68% (51)	12% (9)
Mixing aggression is a problem on my farm (75)	2	9.3% (7)	64% (48)
I avoid mixing unfamiliar pigs wherever possible (74)	5	79.7% (59)	13.5% (10)
It is possible to control aggression at mixing (73)	3	32.8% (24)	28.7% (21)
UK standards of pig welfare are sufficiently strict (68)	4	66.2% (45)	17.7% (12)
The welfare of my animals is important to me (76)	5	97.4% (64)	2.6% (2)
The welfare of my animals is good (76)	5	93.4% (71)	2.6% (2)

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Discrete choice experiment modelling

The RPL model was estimated using all 82 participants, however, in the latent class analysis and the beta regression the number decreased to 52 due to the fact that we used respondent's demographic and attitudinal characteristics. Missing values in any of these variables led to the respondent being omitted by the software.

The results from the RPL model (Table 8) show that preferences, as revealed by the coefficients corresponding to the main effects for each attribute, are significant and positive / negative where expected. That is, estimated installation and running cost coefficients are both negative and statistically significant, indicating that farmers prefer the installation and running costs to be cheaper. The estimated improvement in growth rate and reduction in lesions coefficients are both positive and statistically significant, indicating that farmers prefer a greater improvement in growth rate and a greater reduction in lesions. The coefficient "None" was not statistically significant indicating that farmers did not show a strong preference for either the status quo option (keeping their current farm practice) or the option to make an investment. All of the standard deviation parameters, which indicate how the valuation of the entire sample spreads around the estimated means, are significant, indicating that the preferences were heterogeneous among the sampled farmers. Since all the estimated coefficients were assumed to be normally distributed, the proportion of farmers having positive or negative valuation on each attribute can also be inferred [65]. For instance, we found that 47% of farmers preferred the status-quo option while 53% of them preferred to make an investment. Therefore, since farmers were almost equally split on both positive and negative sides of the preference scale for the status-quo alternative, the positive and negative effect cancelled each other

Table 7. Percentage (number) of farmers to report that they 'currently use', 'used in the past' and 'never used' each aggression control strategy when regrouping unfamiliar growing/ finishing pigs on their farm.

Aggression control strategy (n respondents)	Currently use (n)	Used in the past (n)	Never used (n)
Large social group sizes (65)	50.8% (33)	7.7% (5)	41.5% (27)
Increased space allowance (66)	71.2% (47)	6.1% (4)	22.7% (15)
Adding extra tryptophan to feed (65)	0% (0)	0% (0)	100% (65)
Solid visual barriers/ escape areas (66)	19.7% (13)	7.6% (5)	72.7% (48)
Mixed weight groups (65)	23.1% (15)	9.2% (6)	67.7% (44)
Mixing at night/ low light levels (64)	7.8% (5)	6.3% (4)	85.9% (55)
Novel enrichment material (68)	66.2% (45)	10.3% (7)	23.5% (16)
Tranquilisers (e.g. azaperone) (65)	4.6% (3)	12.3% (8)	83.1% (54)

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Table 8. Estimated farmers' preferences as indicated by the random parameter logit (RPL) model and latent class model (LCM) with 3 classes. The statistical significance associated with the standard deviation indicates whether preferences are heterogeneous among the sampled farmers.

Variables	RPL model		3 class model		
	Mean	Std	Class 1	Class 2	Class 3
None	-0.272	3.416***	15.040	0.270	-1.045***
Installation cost	-0.478***	0.306***	-18.932	-0.620***	-0.244***
Running cost	-2.391***	2.824*	-5.518	-2.877***	-0.968**
Reduction in lesions	0.028***	0.023***	-0.701	0.013	0.026***
Improvement in growth rate	0.367***	0.266***	6.412	0.455***	0.276***
Class share	1		0.18	0.32	0.50

(***) (**) and (*) denote statistical significance at (1%), (5%) and (10%) level, respectively

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out leading to a non-significant effect of the variable “None”. The percentages 47% and 53% were calculated using $100 \times \Phi(-B_k/S_k)$, where Φ is the cumulative standard normal distribution and B_k and S_k are the mean and the standard deviation, respectively, of the “None” coefficient.

Reduction in lesions. The results from the RPL model, displayed in Table 8, show that respondents were more likely to choose an aggression control strategy that would result in a greater reduction in lesions. The computed WTP values are displayed in Table 9 and show that respondents' WTP for an aggression control strategy increased by £0.06 per pig place (installation costs) and £0.01 per pig produced (running cost) for each 1% reduction in lesions. However, the standard deviations are significant (Table 8), which implies that farmers' preferences were heterogeneous. Table 9 shows that among all respondents, those forming Class 1 (18% of respondents) and Class 2 (32% of participants) were unwilling to pay anything to reduce lesions. However, those in Class 3 (50% of participants) were willing to pay £0.11 per pig place (installation cost) and £0.03 per pig produced (running cost) for each 1% reduction in lesions.

Improvement in growth. Farmers were more likely to invest in an aggression control strategy that provided improvements in growth rate (Table 8). In terms of WTP, farmers were willing to pay a price premium of £0.77 per pig place (installation cost) and £0.15 per pig produced (running cost) for each 1% improvement in growth rate (Table 9). However, again the estimated standard deviations are statistically significant, suggesting that farmers' preferences for the attribute “Improvement in growth rate” were heterogeneous. The results from the latent class analysis (Table 9) show that the members of Class 1 were unwilling to pay any installation or running costs for an improvement in growth rate. Class 2 respondents were willing to pay £0.73 per pig place (installation cost) and £0.16 per pig produced (running cost)

Table 9. Farmers' willingness to pay (WTP) (in British pounds, £).

Variables	Random parameter logit model (RPL)	3 class model		
	Mean	Class 1	Class 2	Class 3
Installation cost per 1% reduction in lesions	0.06***	-0.04	0.02	0.11***
Running cost per 1% reduction in lesions	0.01***	-0.13	0.00	0.03**
Installation cost per 1% improvement in growth rate	0.77***	0.34	0.73***	1.13***
Running cost per 1% improvement in growth rate	0.15***	1.16	0.16***	0.29**
Class share	1	0.18	0.32	0.50

(***) (**) and (*) denote statistical significance at (1%), (5%) and (10%) level, respectively

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for each 1% improvement in growth. Those in Class 3 were willing to pay £1.13 per pig place (installation cost) and £0.29 per pig produced (running cost) for each 1% improvement in growth.

Demographic characteristics of respondent classes. Table 10 shows the results from the Beta regression analysis illustrating the demographic and production system characteristics of the members of the three classes of respondents.

Class 1: this class includes 18% of respondents. Farmers in this class were unwilling to pay any investment or running costs for an improvement in growth rates, or a reduction in lesions (Table 9). The results presented in Table 10 show that compared with the members of the other classes, members of Class 1 were least likely to mix unfamiliar growing/finishing pigs. This class were also least likely to agree with the statements 'it is possible to control aggression at mixing' and 'UK standards for pig welfare are sufficiently strict'. Members of Class 1 were likely to own or manage a farm of medium size and to lesser extent large farms. Furthermore, members of Class 1 were more likely to have high experience.

Class 2: this class includes 32% of respondents. The members of this class were characterized by being most likely to mix unfamiliar growing finishing pigs (Table 10). However, they did not show a significant preference for strategies which reduced lesions (Table 8) and they were unwilling to pay any installation or running costs for a reduction in lesions (Table 9). They did show a significant preference for strategies which improved growth rate (Table 8) and were willing to pay £0.73 per pig place (installation cost) and £0.16 per pig produced (running cost) for each 1% improvement in growth (Table 9). Farms in this class were most likely to be of medium size and to a lesser extent large size, when compared to the other classes. They were most likely to be located in England. Farmers in this class were more likely to have medium experience.

Class 3: This is the largest class, including 50% of respondents. Class 3 were unlikely to mix unfamiliar growing/finishing pigs (Table 10). Nevertheless, this class stands out by comprising of members who were most willing to invest in an aggression control strategy, and were willing to pay the most for each 1% reduction in lesions (£0.11 per pig place and £0.03 per pig produced). Furthermore, they were willing to pay for an improvement in growth (£1.13 per pig place and £0.29 per pig produced) (Table 9). Farmers belonging to Class 3 were most likely to own or manage small farms, and most likely to be located in Ireland. Compared to farmers in the other classes, those in Class 3 were most likely to have low experience. Farmers in Class 3 were most likely to agree with the statements 'when mixing unfamiliar pigs, minimizing aggression is important to me' and 'mixing aggression is a problem on my farm'.

Discussion

Improving animal welfare is likely to incur some costs and to yield some benefits and farmers must trade-off estimates of these relative costs and benefits when deciding whether to implement a change in management. It is possible that a misalignment between the focus of pig aggression research and financial constraints on farmers has resulted in impractical or unaffordable solutions. This may have contributed to the limited uptake of solutions identified by research in commercial practice [2, 17]. The 82 UK and Irish pig farmers that participated in this study were equally split between being willing to invest in a strategy to reduce aggression between growing/finishing pigs and being unwilling to invest. The farmers who were willing to invest were heterogeneous in their preferences and willingness to pay for animal welfare improvements (i.e. reduction in lesions) and business goals (i.e. improvement in growth rate). Farmers were unwilling to invest in aggression control strategies that reduced aggression but did not improve farm productivity.

Table 10. Results from the Beta regression—estimated marginal effects (% change in the probability to belong to one of the three classes).

Variables	Class1	Class2	Class3
Mixing	-80.58***	89.90***	-31.02***
Medium_size	96.16***	121.26***	-101.64***
Large_size	11.72**	94.27***	-56.02***
Low_experience	12.56***	-102.98***	67.04***
High_experience	30.40***	-80.47***	46.42***
Location	-20.57***	51.73***	-29.55***
Minimise_agg	3.80	-0.48	2.69**
Problem_farm	1.56	2.74	4.19***
Poss_control	-5.02*	-1.31	-1.62
UK_standards	-5.44**	-0.03	0.07
Welfare_important	4.21	3.08	-0.19
Log pseudo-likelihood	150.06	177.92	139.93
Number of observations	52	52	52
Wald chi square	3071	37852	6785
Probability > Chi square	0.000	0.000	0.000

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Attitudes and practice regarding aggression

Over 90% of the farmers mixed pigs at least once at their farm, despite the fact that 79.7% reported avoiding mixing wherever possible. Weaning was the most common time for mixing amongst the surveyed farmers. These findings are roughly consistent with two prior surveys of pig farmers [17, 18]. Pigs fight in order to establish dominance relationships when regrouped, and this threatens both farm productivity and animal welfare [2, 16]. Nevertheless, only 9.3% of farmers' in the current study perceived mixing aggression to be a problem on their farm. This is also consistent with two prior surveys of pig farmers which found that the majority of farmers did not perceive mixing aggression to be a problem [17, 18].

Minimizing aggression at regrouping was important to 68% of farmers, and 78% reported that they 'currently use' at least one strategy to reduce aggression when they regroup unfamiliar growing/finishing pigs on their farm. The application of these strategies by farmers is consistent with prior research which found that the most popular strategies in practice were not necessarily consistent with those found useful in the peer-reviewed literature [2, 17, 66]. Despite most farmers implementing strategies to reduce aggression, only 32.8% believed it is possible to control aggression at mixing.

With regards to animal welfare more generally, nearly all farmers valued the welfare of their animals (97.4%) and viewed the welfare of their animals to be good (93.4%). This is consistent with prior research which found that animal welfare is an important interest to farmers due to its close association with economic factors, and for ethical and public approval reasons, yet farmers do not tend to think there is anything wrong with animal welfare in livestock husbandry [67–70]. Finally, although the majority of farmers believed that UK standards of pig welfare are sufficiently strict (66.25%) a subgroup of farmers (17.7%) did not. The majority of farmers who did not believe that UK standards were sufficiently strict were based in England and not Ireland. Therefore, this was not determined by a sub-group of Irish farmers based outside of the UK perceiving UK standards as inferior. Pig farmers generally lack the intrinsic motivation to provide animal welfare standards that exceed minimum legal requirements [7]. Therefore, it is promising that in the current study a sub-group of farmers emerged that held concerns for industry standards of welfare.

Discrete choice experiment modelling

Results revealed that, across all respondents, farmers were more likely to choose an aggression control strategy for growing/finishing pigs that resulted in a greater improvement to growth rate, a greater reduction in lesions, a lower installation cost, and a lower running cost. Respondents' WTP for an aggression control strategy increased by £0.06 per pig place (installation cost) and £0.01 per pig produced (running cost) for each 1% reduction in lesions; and increased by £0.77 per pig place and £0.15 per pig produced for each 1% improvement in growth rate. However, the sampled farmers were not a homogenous group. Three classes of farmer were identified, each differing in their preferences and WTP for additional measures to reduce aggression when regrouping unfamiliar growing/finishing pigs on their farm. These classes also differed on several internal factors (attitudes, perceptions and personal characteristics) and farm-specific factors (size, location) which may have contributed to this heterogeneity, and can be used to identify and target these subgroups with tailored campaigns.

Those forming Class 1 (18% of respondents) did not display preferences for either an improvement in growth rate or a reduction in lesions when choosing whether to invest in an aggression control strategy for growing/finishing pigs, and were unwilling to pay for either of these attributes. However, compared to Classes 2 and 3, members of Class 1 were least likely to mix unfamiliar pigs at the growing and finishing stages of production on their farm; therefore, strategies to reduce aggression at regrouping at these stages of production were unlikely to be useful to these farmers. Farmers in Class 1 were most likely to have high experience of working with pigs; they were least likely to believe that legislative standards for pig welfare are sufficiently strict; and were least likely to believe that it is possible to control aggression at regrouping. Therefore, a reluctance to adopt aggression control strategies by these farmers was not associated with a lack of concern for animal welfare. In fact, concerns for aggression and animal welfare may have contributed to these farmers adopting higher standards of welfare by keeping pigs in stable groups throughout production.

Members of Classes 2 and 3 were both willing to change their current farm practice and invest in an aggression control strategy for growing/finishing pigs as long as certain preconditions were met; however they differed in their preferences for animal welfare and business goals, and in their WTP for these attributes. Members of Class 2 (32% of participants) were most likely to routinely mix unfamiliar pigs at growing and/or finishing. When deciding whether to invest in an aggression control strategy they were interested in the extent to which it improved growth rates, but not the extent to which it reduced aggression. They were willing to pay £0.73 per pig place and £0.16 per pig produced for each 1% improvement in growth but were unwilling to pay any investment or running costs for a reduction in aggression itself. Therefore, these farmers seem to be motivated by business but not animal welfare goals. Meanwhile, farmers in Class 3 (50% of participants) were interested in the extent to which the strategy improved growth rates, and the extent to which it reduced aggression. They were willing to pay £1.13 per pig place (investment cost) and £0.29 per pig produced (running cost) for each 1% improvement in growth rate; and £0.11 per pig place and £0.03 per pig produced for each 1% reduction in lesions, and were therefore willing to pay the most for an aggression control strategy. Farmers in Class 3 were also most likely to perceive aggression as a problem on their farm, and most likely to believe that it is important to minimise aggression at regrouping. This is consistent with prior research which found that farmers who perceived aggression to be a problem on their farm were more willing to implement aggression control strategies in the future [17], and together these studies emphasise the importance of farmers' recognising a welfare problem where one exists.

A wide variety of aggression control strategies have been proposed by research [2, 26], and implementation of these management changes in practice may require initial investment costs (which mainly affect fixed costs), running costs (reflected in variable costs), or a combination of both. Farmers in both Classes 2 and 3 were willing to pay both investment and running costs for attributes that they were interested in. This flexibility means that a wide variety of aggression control strategies could potentially be applied in practice as farmers are not limited to, for example, strategies which only affect variable costs. However, it is currently unknown whether any existing strategies meet the financial constraints set by the farmers' expressed WTP. Therefore, an important next step for future research is to conduct cost-benefit analyses of aggression control strategies in order to assess whether or not any existing strategies are economically viable based on compatibility with these constraints. If any of the previously identified strategies do meet these constraints, a second important step for bridging the gap between research and practice is to promote these strategies in the industry via campaigns tailored according to farmers' preferences. For example, campaigns targeting farmers in Class 2 should emphasise the impact that specific aggression control strategies have on farm productivity, whilst campaigns targeting farmers in Class 3 should emphasise the consequences for both animal welfare and farm productivity. The most efficient way of identifying and targeting farmers in the three classes is through their socio-demographic characteristics. Specifically, farmers in Classes 1 and 2 were likely to own or manage farms of medium or large size, whilst those in Class 3 were likely to own or manage small farms. Furthermore, farmers in Class 2 were more likely to be located in England whilst those in Class 3 were more likely to be located in Ireland. These campaigns may be organised by researchers working on the communication of research findings into the industry. A final direction for future research is to develop new aggression control strategies which fit within the constraints identified in the current study.

Study limitations

It is important to acknowledge the limitations of this study. First, the hypothetical nature of the survey limits extraneous validity, and real purchase behaviour remains unobserved. We cannot guarantee that farmers' choices would be translated into actual buying behaviour. For example, the ethical purchase intentions of consumers are not always expressed in their actual buying behaviour [71, 72]. Nevertheless, we controlled for this as much as possible using a cheap talk script and opt-out reminders (see section 2.1 Experimental design). Second, EU pig farmers are under constant pressure as their profit margins are usually very low and fluctuate frequently [73–75]. In times where the industry is struggling farmers will have a lower WTP but their WTP may change relatively quickly depending on industry performance. Therefore the WTP of farmers identified in the current study is likely to fluctuate over time. Third, no information on farmers' age was collected. Prior research detected a strong, positive correlation between pig farmers' age and number of years' experience working with pigs [76]. Therefore, it is likely that farmers' experience in the current study is confounded with age effects. Fourth, the sample of participants was small due to difficulties in reaching this specialised demographic, and due to the fact that the population of UK and Irish pig farmers with responsibility for making financial decisions is small. This could risk Type II errors due to a lack of statistical power. Nevertheless, the sample size reflects a large proportion of the industry, and was sufficient to detect significant effects and account for heterogeneity in responses. Finally, it was not possible under the current study design to account for economies of scale, whereby costs per pig would have been lower for larger farms due to a proportionate saving in costs gained by an increased level of production. This is important because, when making an

investment in animal welfare, the costs per pig would be lower for farmers in Classes 1 and 2 compared to those in Class 3.

Conclusions

Farmers were heterogeneous in their preferences and WTP for additional aggression control strategies to use when regrouping unfamiliar growing/finishing pigs. Overall the results suggest that farmers should not be considered a homogeneous group regarding the adoption of animal welfare innovations and that researchers should target subgroups of farmers with campaigns tailored towards their preferences and WTP. This study provided an important first step in identifying economically viable solutions based on farmers' demands. A crucial next step is to conduct cost-benefit analyses of aggression control strategies in order to assess whether any meet the demands of farmers identified here. The approach adopted in this study could be extended to other long-standing welfare issues where known solutions are poorly adopted in practice.

Supporting information

S1 Survey. The survey completed by all participants. Includes the instructions given to all participants prior to completing the choice sets, the sixteen choice sets, and questions on attitudes, farm characteristics and socio-demographic characteristics. **Data.** The data underlying the findings of this study are available at https://osf.io/xr5vu/?view_only=9c395a241be94413acfee998c9c12988 (PDF)

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3. Farmers use of aggression control strategies

It was beyond the scope of the above journal article to discuss in detail the extent to which the surveyed farmers employed aggression control strategies on their farm. However, it is of interest and relevance to this thesis.

Therefore, in this section I will expand the discussion regarding the current practice of the surveyed farmers. Minimizing aggression at regrouping was important to 68% of farmers, and 78% reported that they 'currently use' at least one strategy to reduce aggression when they regroup unfamiliar growing / finishing pigs on their farm. The most popular strategy was providing increased space allowance at regrouping which was currently used by 71.2% of farmers, and by a further 6.1% in the past. Providing sufficient space at mixing can allow animals to more easily display submissive behaviour, and thus put an end to aggressive encounters (Randolph et al., 1981; Turner et al., 2000). This is the first estimate of the extent to which this strategy is employed in practice, and its popularity appears to be at odds with the high economic costs associated with reducing stocking densities (D'Eath et al., 2016), and the fact that only 4.9% of respondents were accredited with RSPCA quality assurance which would compensate for these additional costs. However, it is likely that these farmers were referring to the fact that, when regrouping occurs, it is usually when pigs are moved to new housing for the next stage of growth (e.g. from

weaner to grower accommodation). Therefore, at the time of regrouping, pigs are relatively small for their new accommodation and stocking densities exceed legal limits.

Distraction with novel enrichment material was the second most commonly used strategy as used by 66.2% of farmers despite there being no empirical evidence that distraction with novel materials reduces aggression.

Nevertheless, this strategy was judged to be useful for controlling aggression by farmers in the study of Peden et al (2019) and the authors noted that research may have largely ignored practical low-cost strategies that have emerged from practice, such as providing roughage at regrouping. However, there is strong evidence that tail biting can be reduced by provision of enrichment material (D'Eath et al., 2014; da Silva et al., 2016), and it is possible that some farmers assumed tail biting and aggression had the same causation and can be managed in the same way.

Large social group sizes reduce aggressive behaviour as pigs adopt a less aggressive social strategy when the costs associated with aggression outweigh the benefits (Andersen et al., 2004; Samarakone and Gonyou, 2009). Large groups were currently used by 50.8% of farmers in the current study, and these farmers all kept pigs in groups exceeding 16 for finishers and 12

for growers. Groups exceeding 12 are sufficiently large to impact upon aggression levels (Andersen et al., 2004) but much larger groups (> 80 pigs) are more effective (Turner et al., 2001; Samarakone and Gonyou, 2009).

Mixed weight groups reduce aggression by allowing dominance hierarchies to be clearly determined by physical size and strength (McGlone, 1985), and were employed by 23.1% of farmers. However, these groups can restrict access to resources for low weight pigs resulting in increased divergence in weight as pigs grow (Andersen et al., 2000; Marchant-Forde and Marchant-Forde, 2005). Solid visual barriers / escape areas were proposed to allow pigs to put an end to aggressive encounters by facilitating retreat, but show somewhat mixed results in research (Marchant-Forde and Marchant-Forde, 2005; Bulens et al., 2017). Nevertheless, they were currently employed by 19.7% of surveyed farmers. The least used strategies were mixing at night / low light levels and tranquilisers (azaperone), which were employed by 7.8% and 4.6% of farmers respectively. These strategies are not supported by research and can delay rather than reduce aggression (Christison, 1996; Marchant-Forde and Marchant-Forde, 2005; Schwarz et al., 2018). Finally, tryptophan is an essential amino acid included in pig feed at levels required for normal functioning, but when concentrations are increased it can effectively reduce aggression at regrouping (Koopmans et al., 2005; Poletto et

al., 2014). None of the surveyed farmers had tried adding extra tryptophan to feed and this is likely due to the fact it is not readily available to purchase, nor is its supplementation routinely recommended by feed companies, and inconsistent dose responses have been reported (Peden et al., 2018).

Despite most farmers implementing strategies to reduce aggression, only 32.8% believed it is possible to control aggression at mixing. This is likely related to the fact that, apart from keeping pigs in stable groups throughout production, there is no unified solution to eliminate aggression (Peden et al., 2018). It is likely that a combination of strategies is required in order to help pigs more quickly and effectively form dominance relationships, but aggression will persist to some extent as its use is frequently necessary when establishing these relationships (McGlone, 1985).

4. Farmers' willingness to pay in practice

In this study I modelled 82 pig farmers' decisions to invest in aggression control strategies described in terms of four attributes: investment cost, on-going cost, reduction in lesions due to aggression and improvement in growth rate. Systematic variations in product attributes allowed me to identify three farmer sub-groups with independent preferences and willingness to pay. Farmers in Class 1 (18% of respondents) were least likely

to regroup unfamiliar pigs and, therefore, did not require an aggression control strategy. Farmers in Class 2 (32% of respondents) were interested in the extent to which the strategy improved growth rates, but not the extent to which it reduced aggression, and were willing to pay £0.73 per pig place (investment cost) and £0.16 per pig produced (running cost) for each 1% improvement in growth but were unwilling to pay any investment or running costs for a reduction in aggression itself. Finally, farmers in Class 3 (50% of respondents) were motivated by animal welfare, as well as business goals, and were willing to pay £1.13 per pig place and £0.29 per pig produced for each 1% improvement in growth rate; and £0.11 per pig place and £0.03 per pig produced for each 1% reduction in lesions as a result of aggression.

When considering a realistic reduction in aggression of 20%, farmers in Class 3 were willing to pay £2.20 per pig place and £0.60 per pig produced. In practice, farmers' profit margins are small and highly volatile (Dawson, 2009; Marquer, 2010; Niemi and Lehtonen, 2010). This is linked to changeable costs of production due to feed prices, seasons and trading cycles, as well as significant fluctuations in the price farmers are paid on an individual pig basis (AHDB, 2019). For example, in the first quarter of 2019 farmers profit margins were estimated to be negative at -£13.00 per pig produced, whilst in

the third quarter profit margins were estimated as £9.00 per pig produced (AHDB, 2019). It is likely that farmers could pay for aggression control strategies when the industry is performing well, however, when farmers are already losing money they have no capacity to pay even if willing to.

5. Conclusions

In Chapter 5 I recommended that researchers should identify practical and cost effective solutions to pig aggression. This chapter took the first step in addressing this recommendation by utilising an economic choice experiment to estimate farmers' willingness to pay for reductions in aggression and identify heterogeneity in their responses. Results revealed three independent classes of pig farmer, each with independent preferences and willingness to pay. Therefore, farmers should not be considered a homogeneous group regarding the adoption of animal welfare innovations. Instead, campaigns should be targeted at subgroups according to their independent preferences and willingness to pay.

This chapter provides an important first step in identifying practical and cost effective solutions to pig aggression. Furthermore, this chapter provides an

important contribution to the literature regarding the extent to which aggression control strategies are employed by farmers in the UK and Irish pig industries. In the next chapter I take the crucial next step of conducting cost-benefit analysis of aggression control strategies. By estimating their financial consequences I identify the most economically viable solutions, and establish whether any meet the constraints of farmers' willingness to pay.

Supplementary materials: The survey is available in appendix F

Chapter 7: Cost-benefit analyses of aggression control strategies

Abstract

Misalignment between the focus of pig aggression research and financial constraints on farmers may have resulted in impractical or unaffordable aggression control strategies, hence resulting in poor uptake by farmers. Therefore, researchers should identify practical and economically viable solutions. In Chapter 6 I modelled 82 pig farmers' decisions to invest in an aggression control strategy and identified three independent farmer sub-groups, each differing in their willingness to pay (WTP) and preferences for animal welfare and business goals. This chapter takes the crucial next step of conducting cost-benefit analyses (CBA) of aggression control strategies in order to establish whether any meet the demands of farmers' WTP. The three most effective and practical aggression control strategies were evaluated in this study; these were allowing litters to mix prior to weaning, housing pigs in relatively large social groups, and exposing pigs to synthetic maternal pheromones. The control scenario of implementing no aggression control strategy was also evaluated. A key risk of CBA is the estimation of costs and benefits being based on assumptions. In order to minimise this risk a combined approach was employed whereby the costs and benefits of each scenario were estimated by reviewing the academic and industry literature

and by conducting a survey of sixteen pig farmers. Uncertainty was minimised by considering the costs and benefits under 'most likely', 'optimistic' and 'pessimistic' scenarios. The most economically viable strategy was allowing pairs of litters to mix prior to weaning. Exposing pigs to synthetic maternal pheromones did not improve profitability; nevertheless, the economic costs were within the realms of WTP for a subgroup of farmers who were motivated by animal welfare goals. The costs of converting existing buildings in order to house pigs in large social groups exceeded their benefits and were beyond the realms of farmers' WTP. I conclude that pre-weaning socialisation should be central to campaigns promoting the control of aggression in the industry, whilst exposing pigs to synthetic maternal pheromones should be targeted at farmers with specific animal welfare goals. Farmers' profit margins are small and highly volatile; they are likely to be willing to make investments when the industry is performing well but reluctant to do so when it is not. Therefore, the timing of campaigns should take this into account.

1. Introduction

A large body of peer reviewed literature has identified some specific changes to pig management, nutrition and genetics which can reduce the occurrence or intensity of aggression at regrouping (see Chapter 2 for a review of the aggression literature). In Chapter 5 I found that 88.5% of the 122 surveyed farmers had tried an aggression control strategy in the past, however only 41% were willing to implement a strategy again in the future. Farmers' willingness to implement an aggression control strategy at regrouping was influenced by a range of interrelated internal and external factors.

Specifically: 1) their perception of their own ability to make the necessary management changes, 2) their beliefs about the likely outcomes, 3) their perception of aggression as a problem, and 4) their views of relevant stakeholder groups. It is possible that a misalignment between the focus of pig aggression research and financial constraints on farmers has resulted in impractical or unaffordable solutions. Therefore, one of the recommendations borne from these findings was that researchers should identify practical and economically viable solutions. In Chapter 6 I took the first steps in addressing this recommendation through a choice experiment which allowed me to estimate farmers' willingness to pay for reductions in aggression and identify heterogeneity in their responses. This chapter takes

the crucial next step of conducting cost-benefit analyses (CBA) of aggression control strategies.

CBA is a quantitative analytical tool used to aid decision makers by establishing the financial consequences of specific interventions. Monetary units are used to quantify the costs and benefits and to provide a measure of the net benefit. The outcomes of different interventions can be compared to identify the most beneficial and, thus, the best allocation of limited resources. CBA has been widely applied across many fields including health care (e.g. Nichol, 2001), environmental conservation (e.g. William et al., 2016), and transport systems (e.g. Jones et al., 2014). It is an appropriate tool for analysing animal health and welfare interventions as it is possible to place a monetary value on mortality and morbidity in animal production (e.g. (Groenendaal et al., 2015). CBA does not account for non-economic (e.g. ethical/ societal) costs and benefits.

This chapter employs CBA to examine the economic consequences of investing in three different aggression control strategies (converting existing buildings in order to house pigs in large social groups, pre-weaning socialisation of piglets and exposing pigs to synthetic maternal pheromones:

see section 2 'Selection of pig management scenarios'), plus the option of making no investment. The primary aims of this study are: 1) to determine the viability of each aggression control strategy i.e. if they are good investments for farmers; and 2) to establish whether any meet the demands of farmers' WTP as identified in Chapter 6. The first step in conducting CBA involves identifying all possible alternative interventions and choosing those most appropriate for your goals (described in section 2 'Selection of pig management scenarios'). The second step involves estimating in monetary units the costs, benefits and uncertainties of each alternative. A key risk of CBA is the estimation of costs and benefits being based on assumptions. In order to minimise this risk we employed a combined approach whereby the costs and benefits of each pig management scenario were estimated by reviewing the academic and industry literature (described in section 3 'Estimation of costs and benefits: the literature'), and by conducting a survey of pig farmers (described in section 4 'Estimation of costs and benefits: farmer survey'). The final CBA is described in section 5 'The economic model'.

2. Selection of pig management scenarios

I identified the pig management scenarios most appropriate for my goals as those that were found to be effective at reducing aggression based on the greatest consensus in the literature. From those that were found to be the effective at reducing aggression, I only included those that could be realistically implemented by farmers under commercial farming conditions (e.g. where they are dependent upon bought-in products, those products are commercially available). In order to ensure that interventions were comparable I focussed my analyses on those which applied to pig management on commercial units housing growing / finishing pigs intended for slaughter. Although pigs are most commonly mixed at weaning (e.g. Peden et al., 2019b), I focussed on controlling aggression between growing / finishing pigs because farmers perceive aggression as a greater problem between growers / finishers than between weaners, and would be more likely to adopt a solution for these pigs (Camerlink and Turner, 2017). Moreover, aggression at regrouping of growing / finishing pigs has a greater risk of impacting upon growth performance, and more risk of lameness and injuries than at weaning when pigs are lighter and weaker (Camerlink et al., 2018). Therefore, the results of this study are relevant for farmers who regroup at either the growing or finishing stages of production. In Chapter 5

I found that growers were regrouped by 28.7% of 122 surveyed UK and Irish pig farmers and finishers by 16.4%.

In Chapter 2 I reviewed the peer-reviewed literature on pig aggression, and established that aggression control strategies display mixed efficacy in empirical trials. The most promising strategies were: enhancing levels of tryptophan in the feed, providing sufficient space, breeding against aggression, pre-weaning socialisation of piglets, housing pigs in relatively large social groups and exposing pigs to synthetic maternal pheromones. Enhancing levels of tryptophan in the feed increases brain availability of serotonin, and subsequently reduces aggressive behaviour in regrouped pigs (Adeola and Ball, 1992; Koopmans et al., 2006; Li et al., 2006; Shen et al., 2012). However, I eliminated this strategy from the current analysis as farmers are not in control of the tryptophan level of the feed and do not have access to readily available tryptophan supplements. Furthermore, the optimum dose response is currently unknown, and it is unclear how tryptophan can be administered for the necessary period without significant disruption to management. Adequate space allowance allows pigs to more easily display submissive behaviour, and thus more quickly put an end to aggressive encounters (Turner et al., 2000). However, this strategy was

eliminated from the current analysis because the optimum space allowance which would reduce aggression has not been identified and any benefits from reduced aggression would very likely be outweighed by the increase in fixed costs. Additionally, the space allowance required will strongly depend upon the flooring type and feeding system design, which vary widely in the industry. Finally, aggressive behaviour has a genetic component and selection against aggression can be implemented using skin lesions as a genetic indicator trait (Turner et al., 2006; Turner et al., 2009) or through indirect genetic selection (Camerlink et al., 2012). However, genetic solutions were not included in the current study as they require implementation by breeding companies rather than commercial units for growing / finishing pigs. Therefore, the final strategies included in this chapter were: pre-weaning socialisation of piglets, housing pigs in relatively large social groups and exposing pigs to synthetic maternal pheromones. As a control condition, I also included the scenario of taking no action to reduce aggression between pigs.

3. Estimation of costs and benefits: the literature

In this section I will review the academic and industry literature for each pig management scenario under investigation in this study. Specifically, I will

identify the key characteristics of each scenario, and the associated costs and benefits that have arisen as a result of their implementation in empirical trials.

3.1 Pre-weaning socialisation of piglets

Pre-weaning socialisation of piglets (also termed co-mingling) refers to allowing two litters of piglets to mix during the lactation period. Suckling litters are allowed to integrate in the second week of life, when piglets would start to encounter other litters under natural conditions (Stolba and Wood-Gush, 1989), and remain together until weaning. Socialisation occurs naturally in most outdoor systems (Petersen et al., 1989) and in group lactation (i.e., multi-suckling) systems (Van Nieuwamerongen et al., 2014); however, these represent only a minority of the industry in most countries. Pre-weaning socialisation of piglets is the most studied aggression control strategy and there is strong evidence that this social experience results in reduced aggression at weaning (see Chapter 2 for a review of the literature). It is presumed to do so by allowing piglets to learn social skills which permit more rapid formation of stable dominance relationships in later social encounters (D'Eath, 2005; Kanaan et al., 2008; Kutzer et al., 2009; Camerlink et al., 2018). Although the impact of pre-weaning socialisation on aggression

at weaning is supported by extensive research, only one study has investigated whether this effect on behaviour is long-lasting. Camerlink et al (2018) compared pig behaviour in socialised groups to control groups not only at weaning (4 weeks old), but also when regrouped at 8 weeks old during the growing stage of production. At 8 weeks, socialised pigs displayed 19% fewer skin lesions at regrouping, suggesting that the reduced level of aggression is indeed sustained beyond weaning.

Farmers have expressed concerns about economic costs arising due to the impact of pre-weaning socialisation on the practical management of sows and piglets, their behaviour, and their growth (Camerlink and Turner, 2017). A primary concern was the incidence of cross-suckling, which can lead to reduced milk intake due to competitive exclusion of subordinate piglets (Pedersen et al., 1998) and a disruption to sow lactation (D'Eath, 2005). Whilst some studies found that cross-suckling does occur (Wattanakul et al., 1997; Olsen et al., 1998; Maletinska and Špinka, 2001), others did not (D'Eath, 2005; Kutzer et al., 2009). Nevertheless, there is evidence that even where cross suckling is common it does not reduce the overall milk intake of the piglets (Maletinska and Špinka, 2001). Socialisation does not affect pre-weaning growth rate (D'Eath, 2005; Salazar et al., 2018), and can improve weaner

performance by increasing growth rate following weaning (Hessel et al., 2006; Ledergerber et al., 2015). However, by 11 weeks old there are no differences in growth performance between socialised and control pigs (Camerlink et al., 2018); therefore farmers would be unlikely to benefit from greater slaughter weights in socialised pigs. Heightened mortality has been observed in multi-suckling systems where more than two litters were simultaneously co-mingled (van Nieuwamerongen et al., 2015), however it has not been observed when pairs of litters are socialised (D'Eath, 2005).

There is an increased incidence of teat injury observed in sows of socialised litters (Camerlink et al., 2018). These injuries are caused by piglets biting for milk, and have the capacity to incur important economic costs by causing teats to become non-functional; thus, reducing the number of piglets the sow can nurse. Nevertheless, Camerlink et al (2018) suggested that the risks of teat injury can be minimised by considering the circumstances, such as sow and litter health, udder condition, litter size, and differences in age between neighbouring litters. I conducted CBA on the implementation of pre-weaning socialisation between pairs of litters under conventional breeding systems, whereby lactating sows are housed with their litters in individual farrowing crates. In these systems, pre-weaning socialisation requires the modification or removal of barriers between adjacent farrowing pens. I

assumed proper management of the intervention regarding considerations for sow and litter health.

3.2 Regrouping pigs into large social groups (100+ pigs)

When pigs are regrouped into new social groups, aggression occurs as they establish a dominance hierarchy (McGlone, 1985). As the number of dyadic relationships increases with increasing group size, it was hypothesised that higher levels of aggression would subsequently occur in larger social groups (Spoolder et al., 1999). However, aggression per pig is actually reduced in large groups (Turner et al., 2001; Andersen et al., 2004; Samarakone and Gonyou, 2009) and this likely reflects the adoption of a less aggressive, and more cost efficient, social strategy due to the higher number of potential competitors (Samarakone and Gonyou, 2009). Thus, the benefits of establishing dominance relationships with pigs that will be met relatively infrequently do not justify the costs of establishing those relationships in the first place. Furthermore, prior experience of large social groups leads to less aggression at future regroupings (Turner et al., 2001; Andersen et al., 2004; Samarakone and Gonyou, 2009). For example, Samarakone and Gonyou (2009) housed growing pigs in groups of either 18 or 108. In a series of studies, they found that pigs derived from the large social groups were less

aggressive at later regroupings; especially when regrouped into large social groups. The optimum group size for the control of aggression has never been established, and is likely to vary between farms depending on buildings and feeding regimes (Finn, 2004; Douglas et al., 2015). Nevertheless, the group size for growing / finishing pigs must be sufficiently large (more than 12 individuals) to have an impact on aggression levels (Andersen et al., 2004), and much larger groups (>80 pigs) are more effective (Turner et al., 2001; Samarakone and Gonyou, 2009).

The reduced requirement for gates and partitions in large groups allows more efficient use of indoor floor space, and reduced time taken to clean pens (Finn, 2004). Reduced gates and partitions also reduce construction costs (Finn, 2004; Gonyou, 2007); however this economic benefit would only apply to farmers building new units. Labour costs may increase as it is likely to take more time to catch individual pigs for treatment (e.g. vaccinations or tagging) (Finn, 2004). There is evidence that growth performance is compromised in large social groups; Turner et al. (2003) reviewed 20 independent studies using almost 22,000 animals and found that large group sizes reduced food intake in weaners, but not growers or finishers; and depressed growth rate in weaners and growers, but not finishers. The

depressed growth rate of weaners may be explained by the reduced food intake observed at this stage of production. However, the poorer growth rate found during the grower stage cannot be explained by a reduction in food intake, and the authors suggest that this may be caused by the demands of greater locomotory activity. None of the other performance traits measured were influenced by group size. Specifically, these were humoral immunocompetence, susceptibility to specific pathologies, morbidity and mortality rates, and reproductive performance. The authors concluded that large group size may compromise the growth performance of young pigs, but the long-term consequences for other economically important traits is likely to be minor (Turner et al., 2003).

In Chapter 6 I found that the eighty-two surveyed farmers' kept growing pigs in groups of 47 on average (median 39, std 31.6, range 14-200) and finishing pigs in groups of 38 on average (median 25, std 45.3, range 12-240). I conducted CBA on the formation of groups of 100+ in growing / finishing pigs as this is a realistic number that is already achieved by a subgroup of farmers in practice, and it is plausible that groups of 100 can be created by removing fencing between adjacent pens and by making necessary changes to feeders and drinkers. Furthermore, this group size is biologically relevant

as it is sufficiently large to prevent pigs establishing dominance relationships with all group members based upon the same level of dyadic aggression seen in smaller groups.

3.3 Exposing pigs to synthetic maternal pheromones

Pig appeasing pheromone is found in the sebaceous glands of the mammary chains of the lactating sow, and is released through skin secretions in order to regulate nursing behaviours (Morrow-Tesch and McGlone, 1990). Pageat (2001) synthesised a mixture containing several fatty acids similar in composition to this maternal pheromone (Pageat, 2001). This synthetic version reduced the frequency of fights at mixing in breeding sows (Plush et al., 2016), adult pigs (Yonezawa et al., 2009), and weaners under experimental (McGlone and Anderson, 2002) and commercial farming conditions (Guy et al., 2009); and reduced physiological signs of stress in pigs during transport to slaughter (Driessen et al., 2008). The number of skin lesions as a result of aggression is reduced up to seven days following mixing in groups exposed to the pheromone, suggesting that it does not merely postpone the occurrence of aggression but results in the more rapid formation of stable social relationships (Guy et al., 2009). Exposure to pheromones does not affect sow conception rate (Plush et al., 2016) or

immune stress response (Driessen et al., 2008). There is some evidence that exposure to the pheromones at weaning improves growth performance and feed efficiency after weaning (McGlone and Anderson, 2002), however this is not supported by Guy et al. (2009) and there is no evidence that growth performance is improved in growing / finishing pigs.

This synthetic maternal pheromone is currently commercially available on the market in odour diffusers (SIGNS, 2019a). I conducted CBA on the use of these diffusers in accordance with the product instructions.

3.4 Implementing no strategy to control aggression at regrouping

As the use of aggression control strategies in practice is optional, I also included the control scenario of taking no action to reduce aggression at regrouping; whereby no additional costs or benefits are incurred.

4. Estimation of costs and benefits: farmer survey

In this section I will describe a survey of pig farmers which was conducted to facilitate the estimation of the monetary costs and benefits likely to arise when implementing aggression control strategies in practice. The survey was

not used to facilitate the estimation of costs associated with exposing pigs to synthetic maternal pheromones. This is because pheromones are available to buy on the market; therefore associated costs were most appropriately estimated by using commercially available information (described in section 4.1 'Final cost calculations').

4.1 Survey design

Sixteen farmers completed the paper based survey during January 2019.

They were recruited at one farmer discussion group (n=8) and by colleagues at Scotland's Rural College (n=8). Farmers were asked to imagine that they were going to start housing growing / finishing pigs in groups of 100 or more on their farm, and were asked to answer the following questions: *'what initial investments/changes would you need to make? (e.g. would you need to make any specific changes to your farm?)'*, *'how much do think that these changes would cost?'* and *'can you envisage any on-going costs associated with housing growing/ finishing pigs in groups of 100 or more? (e.g. increased labour requirements)'*, *'how much do you think it would cost?'*. In order to ensure that responses were interpreted correctly, farmers were asked to *'please make it clear how these costs are described e.g. per pig, per pen or per year'*. This process was repeated for the pig management scenario of allowing litters to mix prior to weaning. Prior to completing the survey farmers were instructed to answer in hindsight if

relevant. For example, if they already housed growing / finishing pigs in large social groups (100+ pigs) on their farm, they were asked to list the costs that they remember encountering when they made the change. If this had always been their method of production, they were asked to leave the question blank. In order to facilitate the estimation of benefits, farmers were asked to imagine that they experienced a reduction in regrouping aggression of 50% in their growers / finishers and to indicate which positive outcomes that they would expect to see from a list which I provided. Specifically:

improved growth rates, reduced skin lesions/injury, reduced labour requirements, easier animal handling, improved feed efficiency, reduced veterinary costs, improved job satisfaction, reduced mortality, higher sale weight, and 'Other, please specify'.

They were also asked to estimate a monetary value that they would expect to save if aggression was reduced by 50% on their farm. The extent to which aggression is reduced following implementation of an aggression control strategy varies widely in the literature. A figure of 50% was chosen for the purpose of this exercise, however this reflects the optimistic, upper-limit of achievable aggression reduction, and scaling for uncertainty over benefit scenarios was conducted in the analysis. In order to establish whether farmers currently use any of the pig production scenarios under analysis, they were asked for their average group size for growing / finishing pigs, whether they currently allow litters to mix prior to weaning, and whether

they currently apply chemical additives to feed, water or air (e.g. appeasing pheromones, citronella sprays, herbal remedies). In addition, farmers were asked to estimate their current costs per slaughter pig lifetime, and for their socio-demographic and farm characteristics (gender, years' experience working with pigs, farm location, farm size, whether pigs are housed indoors or outdoors and quality assurance accreditation). The survey was piloted with two researchers and one pig farmer and corrected according to their feedback regarding the wording and relevance of questions. Informed consent was obtained for all participants. All responses were confidential and could not be tied back to any individual. No controversial questions were asked and there were no possibilities for causing distress or embarrassment to participants. The full survey is available in Appendix H.

4.2 Survey analysis

In order to make the responses of each farmer comparable, their monetary responses were transformed to describe the costs '*per pig produced*' (British Pounds Sterling, GBP). For example, if a farmer specified an *on-going cost* in GBP per pen, this was divided by their group size for growing / finishing pigs (the number of pigs per pen), thus, providing a monetary value '*per pig produced*'. If a farmer specified an *initial investment cost* in GBP per pen, again, this was divided by their group size for growing / finishing pigs. However,

as this *initial investment cost* would last for *many* production cycles, this provided a monetary value '*per pig place*'. In order to transform '*per pig place*' values into '*per pig produced*' values, I assumed that each intervention would have a lifespan of ten years. For housing pigs in large social groups I calculated, as described below, that each growing and finishing 'place' would occupy 144 pigs over the course of this time period. For example, one farmer estimated that it would cost £3.00 *per pig place* to restructure the pens to keep pigs in large social groups, and this value was transformed into '*per pig produced*' using the below calculation:

$$£3.00 \text{ per pig place} / 144 \text{ pigs over the course of ten years} = £0.02 \text{ per pig produced.}$$

I estimated that 144 pigs would occupy each growing and finishing pig 'place' over the course of ten years based on the following assumptions. Pigs enter the grower shed at around 8 weeks old and the finisher shed at around 15 weeks old, where they are housed until slaughter at around 22 weeks old. Therefore, pigs are housed in the growing / finishing facilities for roughly 14 weeks and this is roughly equally split between the grower shed and the finisher shed. Farmers tailor the size of their sow herd to ensure that the weaner, grower and finisher sheds are always occupied other than during the time taken to clean pens between batches. Without accounting for cleaning, each growing shed and each finishing shed has the capacity for

roughly 7.4 production cycles per year (52 weeks per year / 7 weeks per production cycle). Over the course of ten years this would be roughly 74 pig production cycles per shed. In order to account for time taken to clean pens in between batches, I reduced this to 72 production cycles per shed over the course of ten years (1 day cleaning per batch x 72 batches = 72 days cleaning over the course of ten years). I accounted for both the growing and finishing sheds (72 batches per shed over the course of ten years x 2 sheds = 144 pigs produced per place). These assumptions were based on discussions with three senior animal science researchers, all with extensive experience of pig production.

For allowing litters to mix prior to weaning, the initial cost would be incurred in the farrowing house, rather than in the growing / finishing pens. I estimated that 80 pigs would occupy each farrowing pen place over the course of ten years based on the following assumptions. The majority of sows housed in commercial production systems are moved into farrowing crates or pens roughly 7 days before they are expected to farrow. Sows remain in the farrowing house until their litter is weaned at about four weeks old. Therefore, occupancy is roughly 5 weeks per litter, and without accounting for cleaning, each farrowing pen has the capacity for roughly ten production

cycles per year (52 weeks per year / 5 weeks per production cycle). Over the course of ten years this will be roughly 100 production cycles per pen. In order to account for time taken to clean pens in between batches and the fact that sows will farrow on different days during a one week period, I reduced this to 80 production cycles per shed over the course of ten years (7 additional days per batch x 100 batches = 700 additional days over the course of ten years). These assumptions were based on discussions with two senior animal science researchers, both with extensive experience of pig production.

Two farmers reported that they would need to knock down their current building and replace it if they were to house growing / finishing pigs in large social groups (100+). This is unrealistic in practice, and in this instance farmers would choose an alternative strategy to reduce aggression.

Therefore, these two unrealistically large costs were excluded from the analyses. Descriptive statistics were calculated based on the data converted into the 'per pig produced' scale. All analyses and transformations were conducted in SPSS (version 25) and Microsoft Office Excel (2016).

4.3 Survey outcomes

Farmers (n = 16) had on average 30 years of experience working with pigs (std 16.0, range 6-65), fifteen were male (one unspecified), and all were based in Scotland. Their farms were assured by RSPCA (n=4), Scottish SPCA (n=7), Quality Meat Scotland (n=16) and Red Tractor (n=2). All farmers housed their growing and finishing pigs indoors and farm size varied widely (see Table 1) as is representative of intensive pig farms in the UK (AHDB, 2015; 2018). All farmers' regrouped unfamiliar pigs at weaning, two regrouped at the grower stage and five regrouped at finishing. The average group size for growing / finishing pigs was 64 (std 24.9, range 15-400). Five farmers indicated that they already allow litters to mix prior to weaning on their farm, and two indicated that they use chemical additives to feed, water or air (e.g. appeasing pheromones, citronella sprays, herbal remedies). The farm characteristics and mixing practices were similar to those of the surveyed farmers in Chapter 5 and Chapter 6. Eight farmers provided an estimate of the amount it costs to raise each slaughter pig, with an average cost of £118.13 per pig (std £14.38, range £100 - £135).

Table 1. Mean number of pigs kept at each stage of production.

Stage of production (n)	Mean number on farm (std)	Range
Weaners (15)	1359 (1014.5)	70-4050
Growers (11)	999 (790.8)	70-2600
Finishers (16)	1447 (994.2)	70 -2800
Sows (15)	390 (181.0)	90-800

The costs associated with implementing each aggression control strategy, as estimated by farmers, can be seen in Table 2. In order to allow litters to mix prior to weaning, the majority of farmers indicated only the labour requirements for removal of barriers between adjacent farrowing pens when litters were two weeks old (Table 2). These farmers specified no initial investment costs, and only small or non-existent on-going costs due to the time taken to remove the barriers during each lactation period. For two farmers the costs were higher due to the initial requirement to make structural changes to partitions which would allow removal of barriers at the appropriate time during each production cycle. One farmer anticipated 'increased mortality' in pairs of socialised litters. However this is not supported by the literature (see section 3.1 'Allowing litters to mix prior to weaning').

Table 2. Farmers' survey responses regarding the estimation of initial investment costs and on-going costs likely to arise when implementing each aggression control strategy.

Pig management scenario	<i>What initial investments/changes would you need to make? (e.g. would you need to make any specific changes to your farm?)' (n farmers to specify)</i>	<i>How much do you think that these changes would cost? Mean (n farmers to provide a monetary estimate, std, range)</i>	<i>Can you envisage any on-going costs? (e.g. increased labour requirements) (n farmers to specify)</i>	<i>How much do you think it would cost?' Mean (n farmers to provide a monetary estimate, std, range)</i>
<i>Please imagine that you are going to start allowing litters to mix prior to weaning</i>	Modify walls between adjacent farrowing crates to make the removal of barriers possible (e.g. make gaps/ doors in the wall) (n=2)	£0.03 per pig produced (n=2, £0.03, £0.01- £0.05)	Labour requirements for removing barriers between adjacent farrowing pens when litters are 2 weeks old (n=10)	£0.05 per pig produced (n=10, £0.16, £0.00 - £0.50)
	No initial investments/ changes (n=8)	£0.00 (n=8, N/A)	Increased mortality (n=1)	£0.22 per pig produced (n=1, N/A)
<i>Please imagine that you are going to start housing growing/ finishing pigs in groups of 100 or more</i>	Remove pen divisions (n=8)	£0.04 per pig produced (n=6, £0.05, £0.01- £0.14)	Labour requirements (n=9) (e.g. for more time to pick out fat pigs for slaughter)	£0.67 per pig produced (n=5, £0.48, range £0.04- £1.04)
	Re-design penning (n=1)	£0.08 per pig produced (n=1, N/A)	Lower performance (n=1)	No monetary estimate provided
	Move feeders (n=1)	£0.06 per pig produced (n=1, N/A)	Increased mortality (n=1)	No monetary estimate provided
			No on-going cost (n=2)	£0.00 per pig produced (n=2, N/A)

In order to house pigs in large social groups (100+), the majority of farmers reported that they would need to remove fencing between adjacent pens, and one farmer required greater structural changes by re-designing penning (Table 2). One farmer would need to move feeders in order to ensure access of all pigs to essential resources. The majority of farmers predicted that they would incur increased labour requirements (e.g. more time to pick out fat pigs for slaughter). One farmer anticipated 'lower performance' in large social groups, and indeed large group size may compromise the growth performance of young pigs (Turner et al., 2003); however, this farmer did not provide a monetary estimate of the cost of lowered performance. One farmer anticipated 'increased mortality' in large social groups; however this is not supported by research (see section 3.2 'Regrouping pigs into large social groups (100+)).

To assist the estimation of monetary costs for inclusion in the economic model, I calculated the mean cost of implementing each pig management scenario as estimated by farmers (see Table 3). The costs of increased mortality as predicted by farmers were excluded from these analyses because increased incidence of mortality was not supported by peer-reviewed

research for any pig management scenario (see section 3 'Estimation of costs and benefits: the literature').

Table 3. Mean initial investment cost, on-going cost and total cost of implementing each pig management scenario as estimated by farmers. Only farmers who fully answered the questions regarding the monetary estimation of both initial investment costs *and* on-going costs were included in these analyses. For allowing litters to mix prior to weaning, n=8 farmers fully answered the questions; for housing pigs in large social groups, n=6 farmers fully answered the questions.

Pig management scenario	Mean initial investment cost per pig produced (std, range)	Mean on-going cost per pig produced (std, range)	Mean total cost per pig produced (std, range)
Allowing litters to mix prior to weaning	£0.02 (£0.03, £0.00 - £0.06)	£0.06 (£0.18, £0.00 - £0.50)	£0.08 (£0.17, £0.00 - £0.50)
Housing pigs in large social groups (100+)	£0.05 (£0.06, £0.02 - £0.14)	£0.56 (£0.51, £0.00 - £1.04)	£0.61 (£0.51, £0.02 - £1.15)

The benefits that farmers would expect to see as a result of a 50% reduction in aggression on their farm can be seen in Table 4, and these are consistent with the literature whereby the primary benefits of reducing aggression are likely to arise from alleviating financial losses due to injuries and stress caused by aggression (e.g. McGlone, 1985; Turner et al., 2006). Farmers were given the option to list any further benefits which were not included in the list; however, no farmers specified any additional benefits. Ten farmers estimated the amount of money they would expect to save if they saw a 50% reduction in aggression on their farm, with a mean estimate of £0.30 per pig produced (std £0.55, min £0.00 – max £1.50).

Table 4. Farmers were asked to ‘*Please imagine that you see a reduction in regrouping aggression of 50% in your growers / finishers. What benefits would you expect to see?*’. This table displays the number of farmers to tick each positive outcome from the list provided. Fourteen farmers responded to this section of the survey.

Positive outcome	Number of farmers to tick
Improved growth rates	12
Reduced skin lesions/injury	14
Reduced labour requirements	8
Easier animal handling	6
Improved feed efficiency	10
Reduced veterinary costs	10
Improved job satisfaction	10
Reduced mortality	10
Higher sale weight	1

5. The economic model

5.1 Costs: Allowing litters to mix prior to weaning

The monetary costs of allowing litters to mix prior to weaning as estimated by farmers were included in the final economic model (Table 5). No further costs were likely to arise as indicated by the peer-reviewed literature; therefore no additional penalties were added. As the costs and benefits are highly estimated and likely to vary between farms, it was important to test them under optimistic and pessimistic scenarios. Therefore, the mean cost was identified as the ‘most likely’ cost, and the minimum and maximum values were utilised as ‘optimistic’ and ‘pessimistic’ values respectively (see Table 5).

Table 5. The costs of each pig management scenario as included in the economic model.

Pig management scenario	Costs (£) per pig produced			
	Source of cost	Optimistic	Most likely	Pessimistic
Allowing litters to mix prior to weaning	As estimated by farmers	£0.00	£0.08	£0.50
Housing pigs in large social groups (100+ pigs)	As estimated by farmers	£0.02	£0.61	£1.15
	Lowered growth performance	£1.20	£1.60	£2.00
	Total	£1.22	£2.21	£3.15
Pheromones	Purchasing pheromones	£0.31	£0.39	£0.46
	Labour requirements for placing in pens	£0.01	£0.03	£0.04
	Total	£0.32	£0.42	£0.50

5.2 Costs of housing pigs in large social groups (100+ pigs)

The monetary costs of housing pigs in large social groups (100+) as estimated by farmers were included in the final economic model (Table 5). Additional penalties were applied based on the peer-reviewed literature, which indicated that average daily gain is reduced when housing growing, but not finishing, pigs in large social groups (Turner et al., 2003). Feed intake was unaffected by group size, therefore the feed conversion ratio became poorer with increasing group size, and the reduction in growth rate was not offset by a reduction in feed costs. Although one farmer did predict that lowered performance would occur, no estimate of the associated costs was provided. Therefore, I added a penalty of £1.60 per pig produced to the ‘most likely’ scenario, and £1.20 and £2.00 to the ‘optimistic’ and ‘pessimistic’ scenarios

respectively. These costs were estimated based on the findings of Turner et al (2003) that average daily gain for a growing pig is 0.65 kg per day minus 0.00048 kg per additional pig. To calculate the costs of increasing group size to 100+ pigs, I first assumed that the average group size for growing pigs in the UK industry is 50. This assumption is based on surveying a representative sample of eighty-two UK pig farmers' and finding that they keep growing pigs in groups of 47 on average (median 39, std 31.6, range 14-200) (Chapter 6). Based on the study of Turner et al (2003), the average daily gain per pig housed in a group of 50 is approximately 0.63 kg ($0.00048 \text{ kg per day} \times 50 \text{ pigs} = 0.02 \text{ kg}$, $0.65 - 0.02$). In comparison, the average daily gain per pig housed in groups of 100 is 0.60 kg ($0.00048 \text{ kg per day} \times 100 \text{ pigs} = 0.05 \text{ kg}$, $0.65 \text{ kg} - 0.05 \text{ kg}$). Therefore, increasing group size from 50 pigs to 100 pigs would result in a penalty of 0.03 kg per pig per day ($0.63 \text{ kg} - 0.60 \text{ kg}$).

I calculated the monetary implications of this growth penalty based on the following calculations. According to national data obtained by the Agricultural and Horticultural Development Board (AHDB) Pork, in the first quarter of 2019 the average carcass weight of a UK pig (including both standard and non-standard, i.e. RPSCA assured, outdoor born, outdoor bred, pigs) was 85.11 kg (AHDB, 2019). Farmers were paid on average 143.42 pence

per kg, and thus £122.07 per pig produced ($85.11 \text{ kg} \times 143.42 \text{ pence per kg}$) (AHDB, 2019). However, 'carcass weight' refers to the partially butchered, valuable part of the carcass, and this reflects only approximately 75-76% of the entire animal (AHDB, 2017). Therefore, the average liveweight of an entire UK standard pig at slaughter is approximately 112.73 kg ($85.11 \text{ kg} / 75.5\% \times 100$). Based on the assumption that pigs spend 7 weeks (49 days) in the growing stage of production, pigs housed in groups of 100 would be 1.47 kg lighter at slaughter ($0.03 \text{ kg} \times 49$) than those at an average group size of 50. This reflects a liveweight at slaughter of 111.26 kg ($112.73 \text{ kg} - 1.47 \text{ kg}$), a carcass weight of 84.00 kg ($111.26 / 100 \times 75.5\%$), and a payment of £120.47 per pig produced ($84.00 \text{ kg} \times 143.42 \text{ pence per kg}$). Thus, the most likely cost of reduced growth performance when increasing group size from 50 to 100 pigs is £1.60 per pig produced (£122.07 per pig produced - £120.47 per pig produced). However, it is important to note that the study of Turner et al (2003) was a meta-analysis of a large number of published studies available at that time and no subsequent publications have revised the meta-analysis with new data. Furthermore, the meta-analysis assumes that the impact on average daily gain scales linearly with group size, but this has never been investigated. Therefore, to account for uncertainty in these calculations, the optimistic scenario reflects a 25% reduction in the £1.60 cost per pig (75% of £1.60 = £1.20) and the pessimistic scenario reflects a 25% increase in the £1.60

costs per pig (125% of £1.60 = £2.00). The final costs of housing pigs in large social groups (100+ pigs) as included in the economic model can be seen in Table 5.

5.3 Costs of exposing pigs to synthetic maternal pheromones

Synthetic maternal pheromones are commercially available (SIGNS, 2019a). Therefore, I conducted CBA on the use of synthetic maternal pheromones in accordance with the product instructions and commercially available cost information, and thus did not require the inclusion of synthetic maternal pheromones in the farmer survey. Specifically, diffusers should be placed 1.5m above the ground, one diffuser should be placed every 25m², and the diffusers will release the pheromone for up to 6 weeks following opening (SIGNS, 2019b). Growing pigs weighing 60kg are provided with 0.55m² (Council Directive 2008/120/EC); therefore one diffuser would account for approximately 45 pigs. Price information for pig appeasing pheromone diffusers was not available for use in this study. Therefore, in order to identify the monetary costs for inclusion in the economic model I reviewed the costs of purchasing diffusers for companion animals: cat diffusers cost £16.99 each (Feliway, 2019); dog diffusers cost £13.99 each (Adaptil, 2019) and general pet diffusers cost £21.00 each (Pet Remedy, 2019). Based on the

application instructions and price information described above, I estimated that the cost of purchasing synthetic maternal pheromones would be £0.39 per pig produced (std £0.08, min £0.31 - max £0.47). Specifically: £16.99 / 45 pigs = £0.38 per pig; £13.99 / 45 pigs = £0.31 per pig; £21.00 / 45 pigs = £0.47 per pig; mean = £0.39.

I assumed that the labour requirements of exposing pigs to synthetic maternal pheromones (i.e. placing diffusers in pens) would be ten minutes per diffuser. This assumption was based on reviewing the available information on diffuser implementation (SIGNS, 2019b) and on discussion with one commercial pig farmer and one senior animal science researcher, both with extensive experience of working with pigs. Thus, I added the penalty of £0.03 per pig produced to the 'most likely' scenario, and £0.01 and £0.04 to the optimistic and pessimistic scenarios respectively. A Grade 2 (standard) agricultural worker is required to be paid a minimum of £6.96 per hour (GOV.UK, 2019). Therefore, it would cost £0.03 per pig produced to install diffusers into pens ($£6.96 / 60 \text{ minutes} \times 10 \text{ minutes} = £1.16 \text{ per pen} / 45 \text{ pigs}$). The optimistic scenario reflects it taking 5 minutes to install each diffuser ($£6.96 / 60 \text{ minutes} \times 5 \text{ minutes} = £0.58 \text{ per pen} / 45 \text{ pigs}$), and the pessimistic scenario reflects it taking 15 minutes ($£6.96 / 60 \text{ minutes} \times 15 \text{ minutes} = £1.74 \text{ per pen} / 45 \text{ pigs}$). The final costs of exposing pigs to

synthetic maternal pheromones as included in the economic model can be seen in Table 5.

5.4 Benefits of each pig management scenario

The monetary benefits of reducing aggression as estimated by farmers were used to facilitate the estimation of benefits included in the final economic model. Specifically, farmers' estimated that a 50% reduction in aggression would save them on average £0.30 and this was employed as the 'optimistic' scenario. This is because the extent with which aggression is reduced following implementation of an aggression control strategy varies widely in the literature, and a 50% reduction reflects the optimistic, upper-limit of achievable aggression reduction. The 'most likely' scenario of £0.15 reflects a more expected reduction in aggression of 25% ($£0.30 / 2$). The 'pessimistic' scenario of £0.00 was the minimum benefit as estimated by farmers' and reflects no monetary benefits as a result of reducing aggression (Table 6).

Table 6. The monetary benefits of each pig management scenario as included in the economic model.

Pig management scenario	Benefits (£) per pig produced			
	Benefits	Optimistic	Most likely	Pessimistic
Pre-weaning socialisation	Reduced aggression as estimated by farmers	£0.30	£0.15	£0.00
Housing pigs in large social groups (100+ pigs)	Reduced aggression as estimated by farmers	£0.30	£0.15	£0.00
	Reduced labour requirements when cleaning pens	£0.02	£0.01	£0.00
	Total	£0.32	£0.16	£0.00
Pheromones	Reduced aggression estimated by farmers	£0.30	£0.15	£0.00
Making no investment	N/A	£0.00	£0.00	£0.00

Under animal welfare and organic quality assurance schemes, the additional costs of certain animal welfare improvements can be passed to consumers through product labelling. For example, RSPCA assured pigs benefit from restricted use of farrowing crates and increased space allowances, and consumers pay a price premium for these products (RSPCA, 2016). However, no quality assurance scheme makes any specific requirements with regards to the control of pig aggression. Therefore, the costs associated with reducing aggression cannot be passed to consumers, and cannot be included in the current economic model as a monetary benefit.

Regarding housing pigs in large social groups, an additional benefit was added due to the reduced requirement for gates and partitions which would reduce the time taken to clean pens between batches (Finn, 2004). To estimate these benefits, I assumed that it would take one stockperson 1 hour to clean two pens sized for 50 pigs each, and 55 minutes to clean one pen sized for 100 pigs. This assumption was based on discussion with one commercial pig farmer and one senior animal science researcher, both with extensive experience of working with pigs. A Grade 2 (standard) agricultural worker is required to be paid a minimum of £6.96 per hour (GOV.UK, 2019). Therefore, it would cost £0.07 per pig place to clean two pens sized for 50 pigs each ($\text{£}6.96 / 100 \text{ pigs}$) and £0.06 per pig produced to clean one pen sized for 100 pigs ($\text{£}6.96 / 60 \text{ minutes} \times 55 \text{ minutes} = \text{£}6.38 / 100 \text{ pigs}$). The saving would therefore be approximately £0.01 per pig produced. For the optimistic scenario I assumed that it would take 45 minutes to clean one pen sized for 100 pigs ($\text{£}6.96 / 60 \text{ minutes} \times 45 \text{ minutes} = \text{£}5.22 / 100 \text{ pigs} = \text{£}0.05 \text{ per pig produced}$); thus, saving £0.02 per pig produced. For the pessimistic scenario I assumed that no time would be saved for cleaning.

5.5 The trade-off between costs and benefits

The final step of conducting CBA is to trade-off the relative costs and benefits of each scenario (see Table 7). Results revealed that the only strategy likely to

be economically viable for farmers was allowing litters to mix prior to weaning. The costs of exposing pigs to synthetic maternal pheromones and converting existing buildings to house pigs in relatively large social groups exceeded their benefits, and exceeded the costs of implementing no strategy to reduce aggression, even when considering the optimistic scenario.

Table 7. An overview of the cost, benefit and net benefit (benefit – cost) of each pig management scenario.

Pig management scenario	Costs (£) per pig produced			Benefits (£) per pig produced			Net benefit (£) per pig produced		
	Optimistic	Most likely	Pessimistic	Optimistic	Most likely	Pessimistic	Optimistic	Most likely	Pessimistic
Allowing litters to mix prior to weaning	£0.00	£0.08	£0.50	£0.30	£0.15	£0.00	£0.30	£0.07	-£0.50
Housing pigs in large social groups (100+ pigs)	£1.22	£2.21	£3.15	£0.32	£0.16	£0.00	-£0.90	-£2.05	-£3.15
Pheromones	£0.32	£0.42	£0.50	£0.30	£0.15	£0.00	-£0.02	-£0.27	-£0.50
Making no investment	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00

In Chapter 6 I established that farmers are heterogeneous in their preferences and willingness to pay (WTP) for aggression control strategies. I estimated how farmers trade-off the relative costs and benefits when making investment decisions by modelling 82 pig farmers' decisions to invest in an aggression control strategy. Three farmer sub-groups were identified; farmers in Class 1 (18% of respondents) would not invest in an aggression control strategy as they were unlikely to regroup unfamiliar pigs. Farmers in Class 2 (32% of respondents) were willing to invest in an aggression control strategy, but were only interested in the extent to which the strategy improved growth rates, and were unwilling to pay anything to reduce aggression specifically. Farmers in Class 3 (50% of respondents) were motivated by reducing aggression, and were willing to pay £0.11 per pig place (installation cost) and £0.03 per pig produced (running cost) for each 1% reduction in lesions as result of aggression. In order to convert WTP 'per pig place' into WTP 'per pig produced', I assumed that 144 pigs would occupy each growing and finishing 'place' over the course of the lifespan of each intervention (see section 4.2 'Survey analysis' for justification for this assumption). Based on this assumption, farmers in Class 3 were willing to pay £0.0008 investment costs per pig produced ($£0.11 / 144$) and, in total, £0.0308 per pig produced for each 1% reduction in aggression ($£0.03 + £0.0008$). Thus, farmers in Class 3 were willing to pay an additional £0.77 per

pig produced for a realistic reduction in aggression of 25% (£0.0308 x 25%).

When the WTP of these farmers is taken into account regarding the 'most likely' scenario, synthetic maternal pheromones are also likely to be an economically viable option; but converting existing buildings to increase group size to 100+ pigs remains too costly.

6. Implications

This study estimated the financial consequences of three aggression control strategies for use when regrouping unfamiliar growing / finishing pigs. The primary aims of this study were: 1) to determine the viability of each aggression control strategy, i.e. if they are good investments for farmers; and 2) to establish whether any strategy meets the demands of farmers WTP as identified in Chapter 6. The most economically viable aggression control strategy was allowing pairs of litters to mix prior to weaning, i.e. pre-weaning socialization. For the majority of surveyed farmers, implementing this strategy required only small labour costs associated with the removal of barriers between adjacent farrowing pens. This strategy resulted in economic gains which exceeded those of exposing pigs to synthetic maternal pheromones, conversion of buildings to house pigs in large social groups (100+ pigs), and implementing no strategy to reduce aggression. Therefore,

allowing litters to mix prior to weaning meets the economic demands of farmers in both Classes 2 and 3. Moreover, pre-weaning socialisation is the most studied and promising aggression control strategy identified by the academic literature (Peden et al., 2018). Five of the 16 farmers who participated in the current study already allowed litters to mix prior to weaning on their farm. This is roughly consistent with the finding in Chapter 5 that 47 out of the 122 surveyed farmers employed the strategy. Furthermore, those farmers' who had tried it judged it to be more useful than any other strategy (Ison et al., 2018; Peden et al., 2019a). However, farmers' who have not tried pre-weaning socialisation have expressed multiple concerns about it (Camerlink and Turner, 2017) (discussed in section 3.1 'Pre-weaning socialisation of piglets'). I conclude that allowing litters to mix prior to weaning should be a fundamental component of campaigns promoting the control of aggression in the industry; and it is crucial that these campaigns alleviate farmers' concerns by disseminating results regarding the economic consequences and practical implementation. Such campaigns may be organised, for example, by researchers communicating research findings into the industry.

The costs of exposing pigs to synthetic maternal pheromones were primarily determined by purchasing the commercially available diffusers. These costs exceeded their benefits, and exceeded the costs of implementing no strategy to reduce aggression. Therefore, this strategy does not meet the demands of farmers in Class 2, who are motivated only by business goals. However, this strategy remained within the realms of WTP for farmers in Class 3, who were motivated by animal welfare, as well as business, goals. Thus, synthetic maternal pheromones should also be included in campaigns promoting the control of aggression in the industry; however, they should be targeted specifically at farmers with animal welfare goals. The most efficient way of identifying and targeting farmers in Class 3 is through their socio-demographic characteristics, and the results of Chapter 7 revealed that farmers in Class 3 were likely to own or manage small farms, and likely to be located in Ireland as compared to the UK. Compared to farmers in the other classes, those in Class 3 were most likely to have less experience; and were most likely to agree with the statements 'when mixing unfamiliar pigs, minimizing aggression is important to me' and 'mixing aggression is a problem on my farm'. Two farmers in the current survey indicated that they had tried using chemical additives to feed, water or air (e.g. appeasing pheromones, citronella sprays, herbal remedies); suggesting that a market for such interventions does exist.

The costs of converting existing buildings in order to house pigs in large social groups were primarily associated with slowed growth rates with increasing group size (Turner et al., 2003). These costs exceeded their benefits, and exceeded the costs of implementing no strategy to reduce aggression, even under the 'optimistic' scenario. Therefore, converting existing buildings in order to house pigs in large social groups do not meet the demands of farmers in Class 2. Furthermore, the costs were beyond the realms of WTP for farmers in Class 3. However, in Chapter 5, 45.1% of the 122 surveyed farmers reported using large social groups to reduce aggression, and they found them to be moderately useful (Peden et al., 2019a). The monetary consequences of slowed growth rates were estimated based on the assumption that farmers would increase group size from 50 pigs per pen to 100 pigs. However, large variation in group size, and thus associated costs, exist in the industry. This is illustrated by the finding that the sixteen farmers surveyed in the current study housed growing / finishing pigs in groups of 64 on average (median 39, std 24.9) but this ranged from 15-400. Furthermore, farmers in Chapter 5 kept growing / finishing pigs in groups of 85.6 on average (median 40, std 121.92) but this ranged from 12-600. Finally, the 82 farmers surveyed in Chapter 6 kept growing pigs in

groups of 47 on average (median 39, std 31.6, range 14-200) and finishers in groups of 38 on average (median 25, std 45.3, range 12-240). The costs of increasing group size rely heavily on initial and target group size; therefore campaigns should employ the methodology described in the current study to tailor advice on an individual farm basis. Furthermore, although the costs are not justified if converting existing buildings, it is likely that the cost / benefit ratio will be different when building new sheds from scratch. When building new sheds, large social groups would be associated with substantial reductions in construction costs related to buying fewer pen divisions and water and feed pipes. Large social groups also allow for automatic sorting technology and other precision livestock developments that enable better individual nutrition and care (Brummer et al., 2008). Therefore, campaigns should consider that large groups may be justified if building new sheds, and this might explain the popularity of large groups in the industry.

Farmers in the current study estimated that it costs them roughly £118.13 (std £14.38, range £100 - £135) in production costs to raise each pig, and this is roughly consistent with national production costs as calculated by AHDB Pork (AHDB, 2019). Nevertheless, farmers' costs of production vary widely with feed prices, seasons and trading cycles (AHDB, 2019). Furthermore,

farmers were paid on average £122.07 per pig produced in the first quarter of 2019, but the price farmers are paid on an individual pig basis fluctuates significantly (AHDB, 2019). For example, the difference in price paid between the best and worst month in 2014 was over £17; in 2016 this was as much as £30; and in 2018 this was £6 (AHDB, 2019). Therefore, farmers' profit margins are small, and highly volatile (Dawson, 2009; Marquer, 2010; Niemi and Lehtonen, 2010). Farmers are likely to be willing to make investments when the industry is performing well but be reluctant to do so when it is not.

The aggression control strategies investigated in the current study were selected based on their effectiveness at reducing aggression based on the literature. From those that were found to be effective at reducing aggression, I only included those that could be realistically implemented by farmers under commercial farming conditions (e.g. where they are dependent upon products, those products are commercially available). Only three aggression control strategies met this criterion. This illustrates that, although many aggression control strategies have been proposed by research, very few can be practically implemented and managed by farmers under commercial

conditions. Therefore, researchers should concentrate on developing practical solutions.

7. Strengths and limitations

Animal welfare scientists have a solid understanding of the aetiology of aggressive behaviour between pigs. However, the uptake of this research in practice has been limited. This study provides a valuable initial exploration into the costs and benefits of aggression control strategies. However, an important limitation of the current study is that many of the estimates regarding costs and benefits contain a high degree of uncertainty. This is due to the limited availability of monetary cost and benefit data; the extensive variation in farm size and structure observed in the industry; and the costs and benefits experienced by farmers varying widely over time. Nevertheless, a major strength of the current research is the collaboration with industry stakeholders at all stages. I argue that the assumptions made are the most rational and representative of the industry possible. Furthermore, uncertainty was accounted for by considering the 'optimistic' and 'pessimistic' scenarios. Nevertheless, it is important to acknowledge the limitations of several assumptions here.

When transforming costs 'per pig place' into 'per pig produced' I assumed that the lifetime of each intervention would be ten years. For converting existing growing / finishing sheds in order to house pigs in large social groups, I assumed that 144 pigs would occupy each growing / finishing 'place' over the course of this time period. For allowing litters to mix prior to weaning, I assumed that 80 pigs would occupy each farrowing pen 'place' over the course of this time period (see section 4.2 'Survey analysis'). These values are highly estimated and in reality, the lifetime of structural changes will vary widely depending on the type and quality of construction.

When estimating the monetary costs of reduced growth rate when housing pigs in large social groups (see section 5.2 'Costs of housing pigs in large social groups (100+ pigs)'), I assumed that farmers would increase group size from the initial size of 50 pigs. It was necessary to select an initial group size for the purpose of this study, and this was the best estimate based on prior survey research. However, as described in section 6 'Implications', group size varies widely in the industry and the economic consequences would be more accurate if calculations were tailored for individual farms. Furthermore, I assumed that farmers were paid £122.07 per pig produced. This is the amount farmers were paid in the first quarter of 2019 according to national data (AHDB, 2019). However, as described in section 6 'Implications', the

price farmers are paid on an individual pig basis fluctuates significantly over time. How the industry is performing will strongly influence the ratio of costs and benefits. Finally, based on the study of Turner et al (2003), I assumed a linear relationship between group size and growth rate. However, the linearity of this relationship has never been investigated.

When estimating the costs of exposing pigs to synthetic maternal pheromones (see section 5.3 'Costs of exposing pigs to synthetic maternal pheromones') I relied on the price of pheromones for companion, rather than farm animals due to cost information for pig pheromones being unavailable. The production and marketing costs are likely to differ between the agricultural and companion animal industries, therefore some differences may occur in pricing.

When estimating the monetary benefits of reducing aggression (see section 4.4 'Benefits of each pig management scenario'), I assumed a linear relationship between financial benefits and the extent to which aggression is reduced. Specifically, farmers' estimated the monetary benefits of an 'optimistic' reduction in aggression of 50%, and their response was scaled in order to account for the 'most likely' scenario of a 25% reduction. The

linearity of this relationship has never been studied. Nevertheless, it is not expected that farmers would be able to sensitively take into account any non-linearity in their monetary estimations should it exist.

A major strength of the current study is that a survey of pig farmers facilitated the estimation of costs and benefits. Farmers' knowledge and experience of pig management mean that the estimations included in the current study are more accurate than could have been estimated by researchers alone. However, the farmers who participated were all based in Scotland and it is, therefore, possible that their estimations are not representative of the UK population of pig farmers (Leat and Revoredo-Giha, 2013). Nevertheless, all farmers who participated in the current study reported housing growing / finishing pigs indoors, as is consistent with the management of growing/ finishing pigs nowadays in the UK in general. Furthermore, the farm characteristics and practices regarding pig aggression observed in the current sample of farmers were similar to those of farmers in Chapter 5 and 6, who were based across the UK and Ireland.

In order to ensure that interventions were comparable I focussed my analyses on those which applied to pig management on commercial units

housing growing / finishing pigs intended for slaughter. In Chapter 5 I found that growers were regrouped by 28.7% of 122 surveyed farmers and finishers by 16.4%. Therefore the results of this study are only relevant for a minority of the industry. Future research should conduct CBA on the control of aggression at weaning for both weaners and sows.

Finally, a major strength of this research is that heterogeneity in farmers' preferences and WTP were considered. Heterogeneity in farmers' preferences and WTP should be considered in future research of this type.

8. Conclusions

This study conducted cost-benefit analyses of aggression control strategies in order to identify economically viable solutions, and establish whether any meet the demands of farmers as identified in Chapter 6. I conclude that pre-weaning socialisation should be central to campaigns promoting the control of aggression in the industry, whilst exposing pigs to synthetic maternal pheromones should be targeted at farmers with specific animal welfare goals. Campaigns should tailor advice regarding group size on an individual farm basis and consider the cost / benefit ratio for farmers interested in building new sheds. Finally, farmers' profit margins are small and highly

volatile. Campaigns should take into account the fact that the cost-benefit ratio is strongly influenced by how the industry is performing; farmers are likely to be willing to make investments when the industry is performing well but be reluctant to do so when it is not. Thus, the timing of campaigns is crucial.

Supplementary materials: The survey is available in Appendix G.

Chapter 8: General Discussion

1. Introduction

Regrouping of unfamiliar pigs is common in commercial farming; this results in an unstable social structure and high levels of physical aggression as animals establish dominance relationships (McGlone, 1985). Aggression remains an important animal welfare issue despite several strategies to reduce the occurrence or intensity of aggression being identified by extensive research. The implementation of aggression mitigation strategies strongly relies on farmers' willingness to participate in such initiatives. The two primary aims of this thesis were (1) to understand the behaviour of UK and Irish pig farmers with regards to aggression between pigs and (2) to identify practical and cost-effective solutions based on farmer demand. In this general discussion I will first describe the current situation regarding regrouping and the control of pig aggression in the industry, as identified by this research. After that, I will review how the results of this research met the two primary aims of this thesis. I will discuss the results in their wider context, elaborate on the implications, the strengths and limitations, describe important directions for future research, and finish with the main conclusions and recommendations of this thesis.

2. The current situation regarding aggression

In Chapter 5 and Chapter 6 I asked farmers about their practices regarding the regrouping of unfamiliar pigs intended for slaughter. Results confirmed that, although almost all farmers avoided regrouping whenever possible, regrouping remains common in commercial practice with farmers regularly mixing unfamiliar pigs up to four times per production cycle. Regrouping was most common at weaning, when housing constraints force almost all farmers to combine multiple litters to form larger social groups. Regrouping is less common during the growing and finishing stages of production, with roughly one quarter of farmers regrouping at each of these stages (in Chapter 5 growers were regrouped by 28.5% of farmers, and finishers by 24.4%; in Chapter 6 growers were regrouped by 25.6% of farmers and finishers by 16.4%). A minority of farmers also indicated that they regroup the small pigs left behind at slaughter age due to requiring further growth (23.8% of farmers in Chapter 5 and 14.1% in Chapter 6).

In Chapter 2 I established that aggression control strategies display mixed efficacy in empirical trials. The most promising strategies identified by research were: enhancing levels of tryptophan in the feed, providing

sufficient floor space, breeding against aggression, pre-weaning socialisation of piglets, housing pigs in relatively large social groups and exposing pigs to synthetic maternal pheromones. However, several of these strategies could not realistically be implemented under commercial conditions (Chapter 2, 5 and 6). For example, farmers are not in control of the tryptophan content of feed and there are no commercially available tryptophan supplements. Furthermore, the ideal inclusion rate in order to reduce aggression has yet to be established.

By reviewing the industry literature (Chapter 2) and through quantitative analysis of survey data (Chapter 5 and Chapter 6) I provided evidence that aggression research has had little impact on commercial practice. The majority of farmers had tried at least one strategy to reduce aggression during their career. The strategies found useful and employed most commonly in practice were, however, inconsistent with strategies found to be useful in research. For example, the most commonly used strategy was distraction with novel enrichment material (employed by 78% of farmers in Chapter 5, and 66.2% in Chapter 6) despite there being no scientific evidence to support the use of enrichment material to reduce aggression. There is strong evidence that tail biting can be reduced by provision of enrichment

material (D'Eath et al., 2014; da Silva et al., 2016), and it is possible that some farmers assumed tail biting and aggression had the same causation and can be managed in the same way. Indeed, a survey of 167 UK pig farmers found that farmers' comments indicated that some respondents refer to tail biting when asked about aggression (Camerlink & Turner, 2017)

3. Aim 1: to understand the behaviour of UK and Irish pig farmers with regard to aggression between pigs

The first aim of this thesis was a required step because understanding behaviours, and the contexts in which they occur, is essential for developing effective evidence-based interventions. This project took care to cover the wide range of factors likely to contribute to farmers' behaviour regarding aggression. Overall, the results are consistent with prior research whereby a wide range of factors such as economic constraints and personal attitudes, perceptions and characteristics have all been found to influence farmers' willingness to improve animal welfare (Willock et al., 1999; Edwards-Jones, 2006; Kauppinen et al., 2010; Kauppinen et al., 2012).

In Chapter 3, I provided evidence for farmers' widespread belief in pigs' capacity to suffer. These beliefs were also held by specialised pig

veterinarians, animal science students, agricultural students, and citizens unrelated to agriculture. Therefore, a lack of belief in pigs' capacity to suffer does not appear to contribute to the non-financial reasons behind farmers' reluctance to control pig aggression. Nevertheless, it remained unclear whether farmers perceive aggression as a source of pig suffering. Therefore, in Chapter 4 I investigated whether farmers underestimate the impact of pig aggression seen in video clips. Results revealed that farmers' (plus specialised pig veterinarians, animal science students and agricultural students) were efficient at recognising the impact of aggressive encounters in-action. However, all groups underestimated the impact of aggression when they did not see the fight occurring. Farmers will not see fights occurring on their farm as frequently as they actually occur, but they will commonly see fatigued animals with injuries as a result of aggression. Therefore, farmers need to better recognise when a problem exists. However, recognition of the issue alone is unlikely to be sufficient to change farmers' behaviour, and in Chapter 5 I conducted an in-depth analysis of the range of factors that may influence farmers' decisions regarding aggression. Willingness to change was influenced by: 1) whether farmers felt able to implement the change, 2) beliefs about the likely consequences, 3) perceptions of aggression as a problem on their farm, and 4) the opinion of

relevant stakeholder groups, with the opinion of veterinarians being particularly significant (Peden et al., 2019a).

4. Aim 2: to identify practical and cost-effective solutions based on farmer demand

The second aim of this thesis builds upon the findings of the previous chapters in order to identify demand-driven solutions. This is important because solutions based on industry input have the capacity to make real improvements to animal welfare in practice. In Chapter 6 I took the first steps in meeting this aim by estimating farmers' willingness to pay (WTP) for aggression control strategies, and identifying heterogeneity in their responses. Three independent groups of pig farmers emerged, each with different WTP and motivation for animal welfare and business goals. Specifically, farmers in Class 1 (18% of respondents) would not invest in an aggression control strategy as they were unlikely to regroup unfamiliar pigs. Farmers in Class 2 (32% of respondents) were willing to invest in an aggression control strategy, but were only interested in the extent to which the strategy improved growth rates, and were unwilling to pay anything to reduce aggression specifically. Farmers in Class 3 (50% of respondents) were motivated by reducing aggression, and were willing to pay £0.11 per pig

place (installation cost) and £0.03 per pig produced (running cost) for each 1% reduction in lesions as result of aggression. By identifying the bounds of management change possible for farmers, it was ultimately possible to identify solutions which were compatible with these constraints in Chapter 7. Specifically, I conducted cost-benefit analyses (CBA) of three of the most practical and promising aggression control strategies, in order to estimate their financial consequences. Allowing litters to co-mingle prior to weaning (also termed early life socialization) was an economically viable aggression control strategy, whereby the monetary benefits outweighed the costs. Exposing pigs to a synthetic maternal pheromone (i.e. the pig appeasing pheromone) was unlikely to improve profitability. However, the costs were within the realms of WTP for the sub-group of farmers who were motivated by animal welfare goals. Changing existing structures in order to house pigs in large social groups (100+ pigs) resulted in high economic costs which were beyond the realms of farmers' WTP. However, the cost to benefit ratio will be different when constructing new buildings rather than modifying existing ones and this strategy may therefore be attractive for those considering new builds.

5. The impact of farmers' role and experience

At various stages of this project, farmers' perceptions of pig aggression and welfare were compared to other stakeholder groups in order to establish the impact of farmers' role and experience. Comparison groups had experience of working with pigs but in a different context (specialised pig veterinarians), had knowledge of agriculture and livestock but no experience of working with pigs (agriculture students and animal science students), and were unfamiliar with animal production (citizens unrelated to agriculture). Some significant differences between comparison groups were detected. First, agriculture students' displayed a lower emotional response to aggression displayed in video clips when compared to farmers and applied animal science students, and judged pig exhaustion to be lower than farmers (Chapter 4). Second, animal science students expressed the greatest beliefs in animals' capacity to suffer (Chapter 3). Finally, citizens unrelated to agriculture perceived, in comparison to farmers, animals as less capable of experiencing boredom (Chapter 3). These differences are likely to occur due to the different frames of reference of stakeholder groups (e.g. Te Velde et al., 2002). A frame of references is based on the entire set of a person's norms, values, knowledge, convictions and interests. Overall, results revealed that farmers' knowledge and experience of working with pigs did not reduce

their perception of pigs' capacity to suffer (Chapter 3), or their responses to pig aggression seen in video clips (Chapter 4).

6. The results in their wider context and their implications for targeted campaigns

This research established an understanding of farmers' behaviour regarding the management of pig aggression and identified practical and cost-effective solutions based on farmer demand. An important next step is to utilise this information in order to initiate a real change in practice regarding the control of aggression. In this section I will provide evidence-based recommendations which have the capacity to encourage a real change in practice.

A major barrier preventing the uptake of aggression research in practice is that very few strategies proposed to reduce aggression can be practically implemented and managed by farmers under commercial conditions (Chapters 2 and 7). Therefore, a primary recommendation of this project is that animal scientists working on the control of aggression should test new strategies for their practicality and cost-effectiveness. This recommendation could also be extended to other welfare issues as solutions are rarely tested

for cost-effectiveness. Furthermore, farmers' concerns should be addressed. For example, farmers express various concerns regarding the impact of pre-weaning socialisation on the practical management of sows and piglets, their behaviour, and their growth (Camerlink and Turner, 2017). Although the research evidence suggests that socialisation does not result in economic costs associated with increased mortality (D'Eath, 2005), reduced growth performance (D'Eath, 2005; Salazar et al., 2018) or cross-suckling (Maletinska and Špinka, 2001; D'Eath, 2005; Kutzer et al., 2009), there is evidence of increased sow teat damage (Camerlink et al., 2018). Therefore, researchers need to study the effects more thoroughly and make a concerted effort to provide evidence to farmers. Finally, communication within the industry must take place through targeted campaigns which take care to consider the wide variety of factors which influence farmers' behaviour. In the remainder of this section I will provide evidence-based recommendations regarding campaign content.

Specifically, campaigns should advise farmers about how to accurately recognise when a problem exists on their farm by scoring lesions on affected animals. Campaign integrity and impact must be ensured by recommending only practical and economically viable aggression control strategies, and

farmer sub-groups should be targeted appropriately based on their independent preferences and WTP. The most efficient way of identifying and targeting farmers is through their socio-demographic characteristics. For example, farmers in Classes 1 and 2 were likely to own or manage farms of medium or large size, whilst those in Class 3 were likely to own or manage small farms. Allowing litters to socialize prior to weaning should be a central recommendation of campaigns targeted at all farmers with breeding stock due to widespread evidence for its effectiveness at reducing aggression (Chapter 2), its ease of practical management, and its impact on profitability (Chapter 7). Exposing pigs to synthetic maternal pheromones should be promoted to farmers with specific animal welfare goals. The practical and economic consequences of these strategies under commercial conditions should be described, and farmers should be given detailed instructions on how to implement them successfully. As farm size and regrouping practices vary widely in the industry, advice would be most effective if tailored for individual farmers. All information should be directed not only at farmers but various stakeholder groups, with special emphasis on veterinarians. Finally, pig farmers' profit margins are small and highly volatile (Chapter 7). As a result, farmers are likely to be willing to make investments when the industry is performing well but be reluctant to do so when it is not. Thus, the timing of campaigns is crucial.

This project confirmed that changing farmers' behaviour is not a simple task and multi-pronged campaigns are required which target a range of interrelated factors. Such campaigns have been successful at changing complex human behaviours in the past. For example, antibiotic use is also determined by a wide range of intrinsic and extrinsic factors such as culture, social norms, education, legislation, attitudes and the age and sex of individuals (Friedman et al., 2007; Visschers et al., 2014; Jones et al., 2015). Campaigns which understood and carefully addressed all of these factors have succeeded in changing human behaviour by reducing antibiotic use in both medical and agricultural practice (Goossens et al., 2005; Sabuncu et al., 2009; Aarestrup, 2012; Harbarth et al., 2015).

7. Mechanisms by which this research could be implemented in practice

This thesis provides a strong platform for making changes to pig welfare. In this section I will review the possible mechanisms for an intervention to influence farmers to reduce aggression. First, veterinarians had the greatest impact on farmers' behaviour in the current thesis (Chapter 5) and this is consistent with prior research (Alarcon et al., 2014). Thus, veterinarians

provide an important mechanism for changing farmers' behaviour.

Veterinarians practicing in the UK pig industry could be informed of the critical recommendations of this thesis through the Pig Veterinary Society (PVS). The PVS holds twice annual conferences to share information within the industry (Pig Veterinary Society, 2020). These conferences are well attended by specialised pig veterinarians, and guest speakers present information on pig health and welfare issues. Therefore, PVS conferences provide an excellent opportunity to inform a large proportion of the industry's veterinarians of the main thesis recommendations. Furthermore, future veterinarians could be made aware of the primary recommendations through their inclusion in University syllabus.

Second, researchers could conduct educational interventions and monitor their effectiveness. Specifically, on-farm training could be provided to educate farmers of the primary findings of this thesis, particularly regarding the economic consequences of aggression and strategies to control it. The impact of this training on farmers' attitudes and behaviour could be monitored, as well as the impact on levels of pig aggression on the farm. This approach was extensively researched by Hemsworth and Coleman (Hemsworth et al., 1994; Coleman et al., 2000; Coleman et al., 2003;

Hemsworth and Coleman, 2011), who provided stockpeople with evidence of the economic implications of stockperson behaviour. As a result, the attitudes and behaviour of stockpeople towards pigs was improved, and in turn, so was the behaviour, productivity and welfare of pigs (Hemsworth et al., 1994; Coleman et al., 2000; Coleman et al., 2003; Hemsworth and Coleman, 2011). These interventions proved effective in small to medium sized commercial farms (Hemsworth et al., 1994), as well as large commercial farms, where peer pressure and social factors may provide a stronger influence (Coleman et al., 2000). No changes in pig behaviour, productivity or welfare were observed in control farms where no intervention was attempted.

Third, as described in section 6 (The results in their wider context and their implications for targeted campaigns), it is important that farmers concerns regarding the practical management of pre-weaning socialisation under commercial conditions are fully addressed. This could be achieved through an industry-supported demonstration trial run on a high-throughput fully commercial farm and conducted by stockpeople, rather than by researchers. This approach has succeeded in establishing the commercial implications of the free farrowing system PigSAFE (King et al., 2018).

Finally, the Behaviour Change Wheel is model of human behaviour which links the causes of behaviour to mechanisms by which interventions can be conducted. Utilisation of this model when conducting the current research could have allowed an intervention strategy to flow more naturally out of the analysis. This is discussed in greater detail in the following section (8 'The importance of understanding human behaviour regarding animal welfare issues').

8. The importance of understanding human behaviour regarding animal welfare issues

Aggression is one of many animal welfare issues which persist in practice despite animal scientists having a strong understanding of the problem; as well as knowledge of specific changes to management, breeding, housing, and handling which can improve animal welfare (Rushen, 2003; Millman et al., 2004; Dawkins, 2007; Dwyer et al., 2016; Peden et al., 2018). Animal welfare is a complex and multi-faceted issue which includes scientific, ethical, social, economic and political dimensions (Lund et al., 2006). It is determined immediately by animal caregivers (farmers and veterinarians) but also by legislators, consumers and retailers. Therefore, it is clearly not enough to understand only the animals' behaviour. The social sciences

include a broad range of disciplines relevant for the improvement of animal welfare, such as anthropology, philosophy, business and management, politics, economics, psychology, education, sociology, government policy, and law (Lund et al., 2006). Animal scientists will continue to be central for achieving improvements in animal welfare, however the role of the social sciences cannot be underemphasised. Approximately 70 billion land animals are raised and slaughtered by humans, for human consumption, worldwide each year, and this number is expected to continue rising with the growing human population (FAO, 2009; Compassion in World Farming, 2013). Therefore, applying the social sciences in order to understand the behaviour of human stakeholders has the capacity to have a huge impact on farm animal welfare.

Future research into stakeholders' behaviour regarding animal welfare may benefit from recent developments in the field of human behaviour change. The Behaviour Change Wheel (BCW) provides a structured approach to designing interventions which will change specified human behaviours (Michie et al., 2011). The BCW uses a simple, but comprehensive, framework which can be applied to any behaviour (see Figure 1) (Michie et al., 2011; Carroll and Groarke, 2019). At the centre of the wheel, *capability*, *opportunity* and *motivation* are proposed as interacting determinants of behaviour.

Capability may be physical (e.g. affordability) or psychological (e.g. awareness); *opportunity* may be physical (e.g. availability) or social (e.g. social norms or pressure); and *motivation* may be reflective (e.g. personal goals) or automatic (e.g. habit). The *opportunity* component reflects the context; therefore, unlike traditional behaviour change models such as the Theory of Planned Behaviour (TPB) (Ajzen, 1985), the BCW accounts for the social, political and economic context of the behaviour. Survey or interview questions should be designed around this framework in order to gain a comprehensive understanding of the behaviour. The source of behaviour can then be linked to suitable interventions. Depending on the behavioural determinants, there are nine possible intervention functions (see the middle layer of the wheel: Figure 1). These reflect broad categories of means by which an intervention can change behaviour. Having selected the intervention type most likely to be effective, these can then be linked to policy categories which support the delivery of the behaviour change intervention (see the outer section of the wheel: Figure 1).

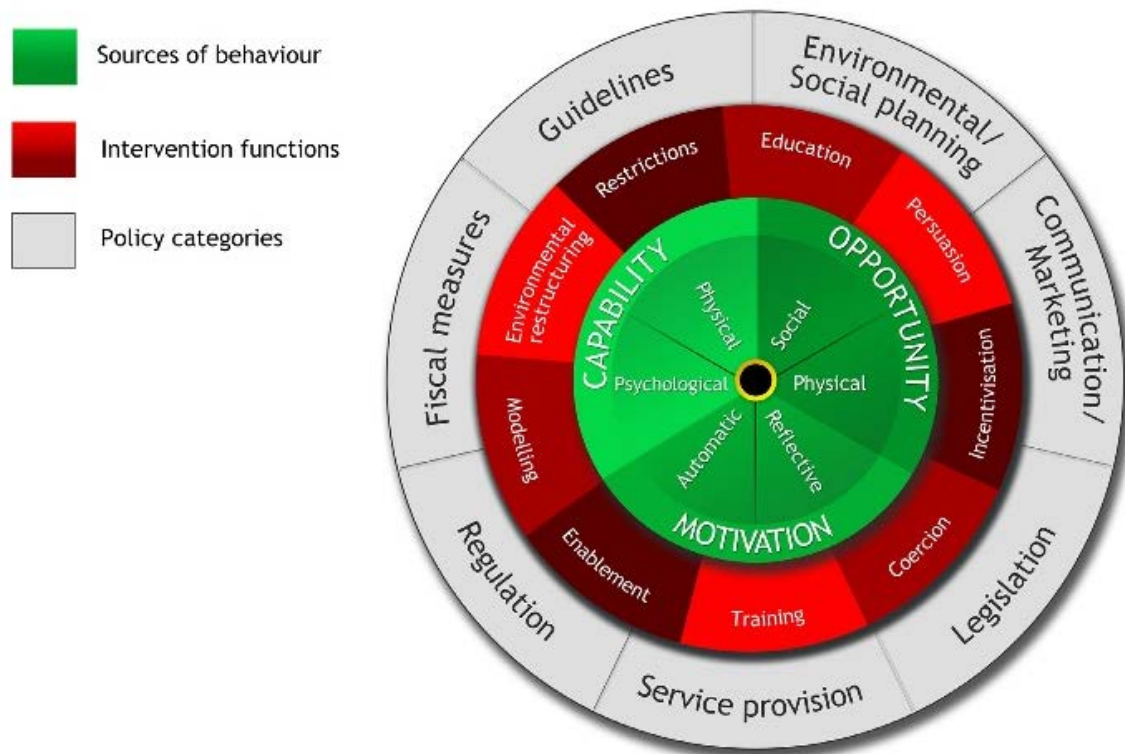


Figure 1. The behaviour change wheel (reproduced from: (Michie et al., 2011) displaying in the inner-most layer the core capabilities, opportunities, and motivations that are considered sources of behaviour. The middle layer outlines the ways that sources of behaviour can be influenced through nine possible intervention functions. The outer layer outlines seven policy categories.

Only a small number of studies have applied the BCW to animal welfare issues, and usually retrospectively rather than using the theory to frame the design of the study from the beginning (Malik and Bradbury, 2016; McDonald et al., 2018; Cornish et al., 2019). However, a dialogue was opened by (Carroll and Groarke, 2019) who emphasised that the BCW can provide a useful tool for developing suitable interventions to encourage uptake of animal welfare research in practice whilst overcoming the weaknesses of

more traditional models of human behaviour, such as the TPB (weaknesses of traditional models were discussed in greater depth in Chapter 5: section 4 'Limitations'). Chapter 5 of this project was highly influenced by the Theory of Planned Behaviour (TPB). This is because the hypotheses were based on the literature investigating farmers' decisions regarding animal welfare, and the TPB has dominated this literature; but going forward I would like to emphasise that the BCW has advantages which should be considered.

9. Strengths and limitations

This thesis is the first body of work to study farmers' decisions and behaviour regarding the longstanding animal welfare issue of aggression between pigs. This research collected quantitative survey data through a combination of novel techniques (Chapter 4) and traditional techniques applied to a novel subject area (Chapters 3, 5, 6 and 7). The novel methodology employed in Chapter 4 involved comparing farmers' and non-farmers' perceptions of aggression exhibited in video clips to objective, physiological measures of the severity of the welfare threat. This innovative methodology has not been applied before and may represent a useful tool to assist in establishing stakeholder perceptions of other stubborn animal welfare issues. In the remaining research chapters (Chapters 3, 5, 6 and 7) I

employed traditional and well-established social science techniques but applied them to a novel area. For example, the survey employed in Chapter 3 was designed and successfully utilised in prior research with different demographic groups (Paul and Podberscek, 2000). Furthermore, structural equation modelling (Chapter 5), choice experiments (Chapter 6) and cost-benefit analyses (Chapter 7) are all established and widely employed techniques used to understand human behaviour and design suitable interventions (e.g. in healthcare: Green, 2012). However, they have scarcely been employed to understand farmers' behaviour regarding animal welfare, and never applied to the problem of aggression between pigs. Therefore, a strength of the current project is the use of powerful and reliable tools which successfully identified the social and economic factors influencing farmers' behaviour and suitable interventions. The approach adopted in this project should be extended to other long-standing animal welfare issues where known solutions are poorly adopted.

The research methods employed in this project were entirely quantitative. Quantitative data is numerically based and amenable to statistical hypothesis testing whereby theories can be ultimately supported or rejected, whilst qualitative data is primarily explorative and used to uncover trends in

thoughts and opinions (Walliman, 2006). There are benefits of using a combination of both qualitative and quantitative research methods in identifying and measuring attitudes. For example, Kauppinen et al (2010) used a combination of both qualitative interviews and quantitative survey research and noted that the interview data greatly facilitated the interpretation of the survey data. Therefore, one weakness of the current project is the absence of qualitative techniques. It would be useful to conduct qualitative research to support, build upon and further interpret the findings of this research.

The two primary methods of measuring the strength of psychometric responses in surveys are visual analogue scales (VAS) and numerical rating scales. This research employed VAS in Chapters 3 and 4, and 7-point numerical rating scales in Chapter 5. Both of these techniques have strengths and limitations which are acknowledged here. VAS are 100mm lines, anchored by word descriptors at each end. Participants mark on the line the point at which they feel best represents their psychometric response, and their score is determined by measuring (in mm) from the left end of the line to the point that the participant marks. Numerical rating scales employ discrete numbers which often correspond to word descriptors (e.g. 1 =

strongly disagree; 2 = disagree; 3= somewhat disagree; 4 = neither agree nor disagree; 5= somewhat agree; 6 = agree; 7 = strongly agree). VAS were employed in Chapters 3 and 4 as the perceptions measured likely ranged across a continuum. For example, from the farmers' perspective, their motivation to intervene during a fight between pigs appears continuous and does not take discrete jumps (Chapter 4). Therefore, the VAS captured the underlying continuum which would not have been captured by numerical rating scales. Although numerical rating scales provide less fine-grained responses, they were employed in Chapter 5 due to their ease of administration in the lengthy survey. Inclusion of VAS would have greatly increased the number of pages that the survey occupied, and thus increased farmers' perceived workload and threatened their participation.

Nevertheless, both are validated methods which are easily understood by participants and quickly administered. However, they also share similar disadvantages in that they attach a single number to a complex, multidimensional experience, and that the intervals between values cannot be presumed to be equal (Correll, 2006; Sung and Wu, 2018). Guyatt et al (1987) measured the quality of life of chronic lung disease patients before and after treatment through surveys which utilized either seven-point scales or VAS. They found similar outcomes in both groups, and concluded that the two methods show comparable responsiveness, but recommended the use of

seven-point scales due to their ease of administration and interpretation (Guyatt et al., 1987). Therefore, both techniques were appropriate for use in this research whereby constructs were analysed which could not easily be directly measured.

This research focussed only on the management of aggression between growing / finishing pigs intended for slaughter. Nevertheless, it is important to note that sows are also frequently regrouped when returned to group housing following weaning (KilBride et al., 2012; Greenwood et al., 2014; Chidgey et al., 2015). Sows are usually served within one week following weaning and aggression can disrupt embryonic implantation (Arey and Edwards, 1998; Greenwood et al., 2014). There are important differences between breeding and fattening stock regarding their housing systems and financial value. Therefore, it is likely that cost-benefit analyses of aggression control strategies would have different outcomes when applied to breeding stock compared to growing / finishing pigs, and that farmers' perceptions of the problem and willingness to adopt solutions would also differ. An important direction of future research is to investigate the social and economic factors influencing the control of aggression between breeding sows. Sow management systems differ within and between countries. For

example, mixing of unfamiliar sows occurs around the time of service in some countries (e.g. the UK) but is delayed until after embryonic implantation in other countries (e.g. most of the EU). Furthermore, some farmers adopt dynamic housing systems where the composition of gestating sow groups changes each week by the entry and exit of some animals.

Modelling the cost-effectiveness of strategies to reduce sow aggression would need to take account of these complexities. The physiological state and strategy for mixing younger pigs (e.g. growers) is more standardised across farms and countries. To this end, the findings and recommendations from this thesis ought to have broad relevance beyond the UK and Ireland.

This thesis took the position that farmers', as animal caregivers, are primarily responsible for implementing strategies to reduce aggression. However, as described in section 6 ('the importance of understanding human behaviour regarding animal welfare issues'), various stakeholders have the capacity to influence animal welfare in practice. A strength of this project is that, at various stages, the perceptions of further stakeholder groups were addressed (specialised pig veterinarians, agriculture students, animal science students, and citizens unrelated to agriculture). However, it was beyond the scope of this project to address the perceptions of consumers and retailers who also

have the capacity to influence animal welfare standards (e.g. Lever and Evans, 2017). No research has addressed consumers perceptions of aggression in pig farming, whereas consumer perceptions have been addressed regarding other pig welfare issues (e.g. immunocastration: Mancini et al., 2017). Nevertheless, the legislation and quality assurance standards do not provide specific recommendations on appropriate measures to take to reduce aggression between pigs (Council Directive 2008/120/EC; RSPCA, 2016; Quality Meat Scotland, 2017; Soil Association, 2018; Red Tractor Assurance, 2019). As a result, consumers and retailers are unable to influence market demand for products from farms with low aggression.

In recruiting participants for social research such as this, several types of bias are a risk. First, sampling bias can occur when certain members of a population are less likely to be included than others. Second, self-selection bias can occur when individuals participate based on interest in the study. Finally, social desirability bias can occur if participants act in a way that they believe is deemed to be favourable by others (Rosenthal, 1976). In the remainder of this section I will review the recruitment methods and

participants included in this research, the measures taken to minimise bias, and acknowledge where any bias may have been introduced.

Recruitment of pig farmers for surveys remains difficult (Ison and Rutherford, 2014) and studies must be carefully designed to avoid bias towards including only proactive farmers. Farmers were mainly recruited by targeting producer discussion groups (Chapters 3, 4, 5, 6 and 7), and a minority were recruited via the post and online (Chapter 5). Producer discussion groups are organised, usually quarterly, in each of the pig producing regions of the UK and each is attended by between 10 and 40 farmers. The focus of the meetings is to improve technical efficiency and profitability and they are attended by farmers from across the spectrum of the industry regarding herd size and methods of production. Animal welfare topics are not usually discussed at these meetings, and farmers were unaware that they would be asked to participate in animal welfare research prior to attending. Therefore, they were not self-selected with regards to specific welfare views, which is a risk when recruiting farmers through postal or telephone surveys. However, there is a risk that these farmers were more progressive than the population in general. Nevertheless, by employing this recruitment technique I successfully recruited farmers that

matched the sex and age demographic and herd size distribution of full-time farmers in the UK (Defra, 2017). Furthermore, I was able to target farmers employed in a variety of farm roles (Chapter 3, 4 and 5), as well as to strategically sample those responsible for financial decisions (Chapter 6). Recruitment at discussion groups allowed efficient data collection whereby all group members participated simultaneously. Sample sizes were similar to, or exceeded, that of similar research (Camerlink and Turner, 2017) and were sufficient to detect significant effects and account for heterogeneity in responses. Farmers who voluntarily responded via post or online were likely to be progressive and interested in the survey content. These farmers may, therefore, have introduced some bias into the sample, although they were few in number.

Veterinarians (Chapters 3 and 4) were primarily recruited at the same producer discussion groups as the farmers. Therefore, these participants were also unlikely to have been self-selected with regards to specific welfare views, and were located across the UK and Ireland. A minority of veterinarians were recruited through snowball sampling whereby veterinarian participants recruited other veterinarians. This is an established technique for recruiting hard-to-reach or specialised demographics (Babbie,

2010). The sample of specialised pig veterinarians was small due to difficulties in reaching this small and specialised demographic, and this could risk Type II errors due to a lack of statistical power. Indeed, no significant effects were detected for this comparison group.

Undergraduate students of Animal Science and Agriculture courses were recruited following scheduled lectures and field trips held at Scotland's Rural College (Chapters 3 and 4). Students were unaware that they would be asked to participate in animal welfare research before attending the event. Therefore, they were not self-selected based on interest in the study content. However, they are not necessarily representative of Animal Science and Agriculture students studying at other institutions. Again, sample sizes were small and this could risk Type II errors due to a lack of statistical power; nevertheless some significant effects were detected for these groups (Chapters 3 and 4).

Citizens unrelated to agriculture were recruited by one staff member and six PhD students based at Scotland's Rural College, who recruited friends and relatives in their home towns (Chapter 3). This method of recruitment was

used in previous published research studying citizen attitudes towards animal welfare (You et al., 2014), and allowed us to recruit people from across the UK and Ireland who did not know the purpose of the study. Therefore, I avoided participant self-selection based on interest in the study. Respondents who were direct family members and others with knowledge of the purposes of the PhD study were not recruited. However, it is possible that citizens shared some values with researchers which may have influenced their results.

Throughout this research I minimised social-desirability bias by ensuring that participants' were aware that all responses were confidential and could not be tied to any individual. Furthermore, when participating in groups, all group members were instructed not to discuss the task, in order to avoid influencing one another's answers.

10. Conclusions

Animal welfare scientists have a solid understanding of the aetiology of aggressive behaviour between pigs. However, the uptake of this research by farmers in commercial practice has been limited. This thesis is the first body of work to study the social and economic barriers which determine the

uptake of aggression research in practice, and confirmed that a range of interrelated factors are important. These include the practical and economic consequences of aggression control strategies, and farmers' perceptions, attitudes and socio-demographic characteristics. As a result, researchers should establish the practicality and cost-effectiveness of new aggression control strategies under commercial conditions. Furthermore, farmers should be targeted with tailored campaigns which are transparent about the costs and benefits of aggression control strategies, and which take care to address the wide range of factors which influence farmers' behaviour. Furthermore, campaigns should consider the heterogeneity in the population. This thesis makes several evidence-based recommendations regarding the design of these targeted campaigns.

Bullet points of main conclusions

1. There has been limited uptake of extensive aggression research in commercial practice.
2. A lack of belief in pigs' capacity to suffer does not contribute to the non-financial reasons behind farmers' reluctance to control pig aggression.

3. Farmers need to better recognise the impact of aggression in the absence of seeing the fight occur.
4. Farmers' willingness to reduce aggression on their farm is influenced by a range of interrelated factors.
5. Farmers are heterogeneous in their willingness to pay for aggression control strategies and their reasons for making an investment. Groups with different willingness to pay can be identified by demographic characteristics.
6. Allowing litters to co-mingle (i.e. socialize) prior to weaning is the most promising, practical and cost-effective aggression control strategy identified by research.
7. Exposing pigs to synthetic maternal pheromones is unlikely to improve profitability but the costs are within the realms of willingness to pay for farmers with specific animal welfare goals.
8. Changing current structures in order to house pigs in large social groups (100+ pigs) is associated with high economic costs which are beyond the realms of farmers' willingness to pay.
9. Few of the aggression control strategies proposed by research can be realistically implemented and managed by farmers under commercial conditions.

10. The social sciences have the capacity to make valuable contributions to improving animal welfare.

Bullet points of main recommendations

1. Animal scientists working on the control of aggression should test new strategies also for their practicality and cost-effectiveness.
2. Communication within the industry should take place through targeted campaigns which take care to consider the wide variety of factors which influence farmers' behaviour.
3. Campaigns should advise farmers about how to accurately recognise when a problem exists on their farm by scoring lesions on affected animals.
4. Campaign integrity and impact must be ensured by recommending only practical and economically viable aggression control strategies.
5. Farmer sub-groups should be targeted appropriately based on their independent preferences and WTP.
6. Allowing litters to socialize prior to weaning should be a central recommendation of campaigns targeted at all farmers with breeding stock.

7. Exposing pigs to synthetic maternal pheromones should be targeted at farmers with specific animal welfare goals.
8. The practical and economic consequences of aggression control strategies under commercial conditions should be described.
9. Farmers should be given detailed instructions on how to implement specific aggression control strategies successfully.
10. Advice would be most effective if tailored for individual farmers.
11. All information should be directed not only at farmers but various stakeholder groups, with special emphasis on veterinarians.
12. The approach adopted in this project should be extended to other long-standing animal welfare issues where known solutions are poorly adopted.

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Appendix A

Animal sentience survey for farmers (Chapter 3)

Part 1 – Demographics

Year of birth:

Gender:

(please circle) /Male

/Female

/Prefer not to say

Occupation:

(please circle) /Pig farmer

/Other. Please state

Roughly how many years have you worked with pigs?

Roughly how many of the following do you have on your farm?

Weaners

Finishers

Growers

Sows

Which of the following best describes you? Please tick all that apply

Farm owner

Farm manager

Contract farmer (e.g. bed & breakfast)

Farm worker

Retired

Other. Please specify:

Do you ever intervene during aggressive encounters between pigs on your farm? Please tick ALL statements that you agree with

No, there is no point

No, I never see aggressive encounters on my farm

No, it is too dangerous

Yes, when profitability is likely to be affected

Yes, to reduce injuries /stress for the animals

Other

Please state.....

How often do you eat pork/ ham/ bacon? Please tick

Daily

Weekly

Monthly

Never

Nationality (please specify).....

Location:

England
Scotland

Wales
Northern Ireland

Republic of Ireland
Other, namely:

Part 2 – Questionnaire

To indicate your answer, please put a small vertical line on the horizontal scale where you feel is appropriate as in the example below



Do you think that most **dogs** can feel the **sensation** of **hunger**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **dogs** can feel the **sensation** of **pain**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **dogs** experience the **emotion** of **fear**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **dogs** experience the **emotion** of **boredom**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **cats** can feel the **sensation** of **hunger**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **cats** can feel the **sensation** of **pain**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **cats** experience the **emotion** of **fear**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **cats** experience the **emotion** of **boredom**?

No, not at all | _____ | Yes, in a very similar way to people

Do you think that most **cows** can feel the **sensation** of **hunger**?

No, not at all				Yes, in a very similar way to people

Do you think that most **cows** can feel the **sensation** of **pain**?

No, not at all				Yes, in a very similar way to people

Do you think that most **cows** experience the **emotion** of **fear**?

No, not at all				Yes, in a very similar way to people

Do you think that most **cows** experience the **emotion** of **boredom**?

No, not at all				Yes, in a very similar way to people

Do you think that most **pigs** can feel the **sensation** of **hunger**?

No, not at all				Yes, in a very similar way to people

Do you think that most **pigs** can feel the **sensation** of **pain**?

No, not at all				Yes, in a very similar way to people

Do you think that most **pigs** experience the **emotion** of **fear**?

No, not at all				Yes, in a very similar way to people

Do you think that most **pigs** experience the **emotion** of **boredom**?

No, not at all				Yes, in a very similar way to people

Appendix B

Animal sentience survey for non-farmers (Chapter
3)

Part 1 – Demographics

Year of birth:

Gender: /Male /Female /Prefer not to say
(please circle)

Occupation: Please specify.....
(please circle)

If student/researcher, what is the subject of your studies?

If student, how far into your course are you?

Nationality (please specify).....

Location:

☐	England	☐	Wales	☐	Republic of Ireland
☐	Scotland	☐	Northern Ireland	☐	Other, namely:

Do you have any experience working with pigs? (please circle) YES / NO

If yes, roughly how much experience do you have?

	Days		Months		Years

How often do you eat pork/ ham/ bacon? Please tick

☐	Daily	☐	Weekly	☐	Monthly	☐	Never

Part 2 - Questionnaire

To indicate your answer, please put a small vertical line on the horizontal scale where you feel is appropriate as in the example below



Do you think that most **dogs** can feel the **sensation** of **hunger**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **dogs** can feel the **sensation** of **pain**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **dogs** experience the **emotion** of **fear**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **dogs** experience the **emotion** of **boredom**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cats** can feel the **sensation** of **hunger**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cats** can feel the **sensation** of **pain**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cats** experience the **emotion** of **fear**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cats** experience the **emotion** of **boredom**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cows** can feel the **sensation** of **hunger**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cows** can feel the **sensation** of **pain**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cows** experience the **emotion** of **fear**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **cows** experience the **emotion** of **boredom**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **pigs** can feel the **sensation** of **hunger**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **pigs** can feel the **sensation** of **pain**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **pigs** experience the **emotion** of **fear**?

No, not at all | _____ | *Yes, in a very similar way to people*

Do you think that most **pigs** experience the **emotion** of **boredom**?

No, not at all | _____ | *Yes, in a very similar way to people*

Appendix C

Video study survey for farmers (Chapter 4)

Part 1 – Demographics

Year of birth:

Gender:

(please circle) /Male

/Female

/Prefer not to say

Occupation:

(please circle) /Pig farmer

/Other. Please state

Roughly how many years have you worked with pigs?

Roughly how many of the following do you have on your farm?

Weaners

Finishers

Growers

Sows

Which of the following best describes you? Please tick all that apply

Farm owner

Farm manager

Contract farmer (e.g. bed & breakfast)

Farm worker

Retired

Other. Please specify:

Do you ever intervene during aggressive encounters between pigs on your farm? Please tick ALL statements that you agree with

No, there is no point

No, I never see aggressive encounters on my farm

No, it is too dangerous

Yes, when profitability is likely to be affected

Yes, to reduce injuries /stress for the animals

Other

Please state.....

How often do you eat pork/ ham/ bacon? Please tick

Daily

Weekly

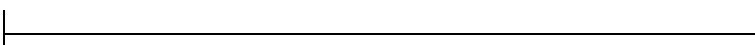
Monthly

Never

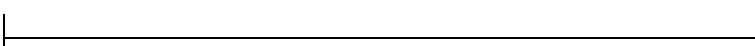
Part 2 – Videos

Clip 1

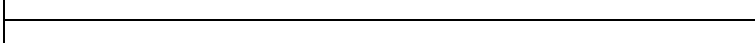
How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction |  | strongest possible negative reaction

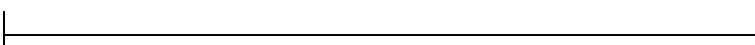
If you saw this fight on your farm, how much would you want to prevent it continuing?

not at all |  | the most possible

How exhausting do you think this situation is for the focal pig?

not exhausting at all |  | the most exhausting possible

How severe do you think this situation is for the focal pig?

not severe at all |  | the most severe possible

How did you judge fight severity? Please tick all factors that you relied on when making your judgement

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Clip 2

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | *strongest possible negative reaction*

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | *the most exhausting possible*

How severe do you think this situation is for the focal pig?

not severe at all | _____ | *the most severe possible*

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐	<i>Number/severity of lesions</i>	☐	<i>Sound - vocalisations</i>
☐	<i>Panting</i>	☐	<i>Sound – other (e.g. banging)</i>
☐	<i>Facial expression</i>	☐	<i>Stress</i>
☐	<i>Other</i>		

Please state.....

Clip 3

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | *strongest possible negative reaction*

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | *the most exhausting possible*

How severe do you think this situation is for the focal pig?

not severe at all | _____ | *the most severe possible*

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐	<i>Number/severity of lesions</i>	☐	<i>Sound - vocalisations</i>
☐	<i>Panting</i>	☐	<i>Sound – other (e.g. banging)</i>
☐	<i>Facial expression</i>	☐	<i>Stress</i>
☐	<i>Other</i>		

Please state.....

Clip 4

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction |-----| strongest possible negative reaction

How exhausting do you think this situation is for the focal pig?

not exhausting at all |-----| the most exhausting possible

How severe do you think this situation is for the focal pig?

not severe at all |-----| the most severe possible

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Clip 5

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | *strongest possible negative reaction*

If you saw this fight on your farm, how much would you want to prevent it continuing?

not at all | _____ | *the most possible*

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | *the most exhausting possible*

How severe do you think this situation is for the focal pig?

not severe at all | _____ | *the most severe possible*

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Clip 6

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | *strongest possible negative reaction*

If you saw this fight on your farm, how much would you want to prevent it continuing?

not at all | _____ | *the most possible*

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | *the most exhausting possible*

How severe do you think this situation is for the focal pig?

not severe at all | _____ | *the most severe possible*

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐ <i>Number/severity of lesions</i>	☐ <i>Sound - vocalisations</i>
☐ <i>Panting</i>	☐ <i>Sound – other (e.g. banging)</i>
☐ <i>Facial expression</i>	☐ <i>Stress</i>
☐ <i>Other</i>	

Please state.....

Appendix D

Video study survey for non-farmers (Chapter 4)

Part 1 – Demographics

Year of birth:

[illegible]

Occupation: /Undergraduate student /Masters Student /PhD Student /Researcher
(please circle)

/Other. Please specify.....

If student/researcher, what is the subject of your studies?

If student, how far into your course are you?

Do you have any experience working with pigs? /Yes /No
(please circle)

If yes, how roughly how much experience do you have?

Days Months Years

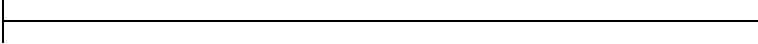
How often do you eat pork/ ham/ bacon? *Please tick*

☐ *Daily* ☐ *Weekly* ☐ *Monthly* ☐ *Never*

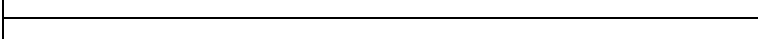
Part 2 – Videos

Clip 1

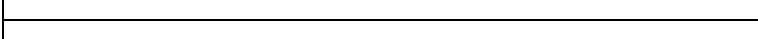
How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction |  | strongest possible negative reaction

How exhausting do you think this situation is for the focal pig?

not exhausting at all |  | the most exhausting possible

How severe do you think this situation is for the focal pig?

not severe at all |  | the most severe possible

How did you judge fight severity? Please tick all factors that you relied on when making your judgement

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Clip 2

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | *strongest possible negative reaction*

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | *the most exhausting possible*

How severe do you think this situation is for the focal pig?

not severe at all | _____ | *the most severe possible*

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐	<i>Number/severity of lesions</i>	☐	<i>Sound - vocalisations</i>
☐	<i>Panting</i>	☐	<i>Sound – other (e.g. banging)</i>
☐	<i>Facial expression</i>	☐	<i>Stress</i>
☐	<i>Other</i>		

Please state.....

Clip 3

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | *strongest possible negative reaction*

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | *the most exhausting possible*

How severe do you think this situation is for the focal pig?

not severe at all | _____ | *the most severe possible*

How did you judge fight severity? *Please tick all factors that you relied on when making your judgement*

☐	<i>Number/severity of lesions</i>	☐	<i>Sound - vocalisations</i>
☐	<i>Panting</i>	☐	<i>Sound – other (e.g. banging)</i>
☐	<i>Facial expression</i>	☐	<i>Stress</i>
☐	<i>Other</i>		

Please state.....

Clip 4

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | strongest possible negative reaction

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | the most exhausting possible

How severe do you think this situation is for the focal pig?

not severe at all | _____ | the most severe possible

How did you judge fight severity? Please tick all factors that you relied on when making your judgement

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Clip 5

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | strongest possible negative reaction

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | the most exhausting possible

How severe do you think this situation is for the focal pig?

not severe at all | _____ | the most severe possible

How did you judge fight severity? Please tick all factors that you relied on when making your judgement

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Clip 6

How much of a negative emotional reaction towards the situation shown on the video do you have?

no negative reaction | _____ | strongest possible negative reaction

How exhausting do you think this situation is for the focal pig?

not exhausting at all | _____ | the most exhausting possible

How severe do you think this situation is for the focal pig?

not severe at all | _____ | the most severe possible

How did you judge fight severity? Please tick all factors that you relied on when making your judgement

☐	Number/severity of lesions	☐	Sound - vocalisations
☐	Panting	☐	Sound – other (e.g. banging)
☐	Facial expression	☐	Stress
☐	Other		

Please state.....

Appendix E

Structural equation model survey (Chapter 5)



Your opinion counts!

Contribute to applied research on the costs and benefits of
practical solutions to reduce aggression between pigs

For my PhD research project I am studying **mixing aggression** in **growing/finishing pigs** and would be grateful if you could answer some questions. The survey will take about 10 minutes to complete. All responses will be treated confidentially and strictly anonymously and individual answers will not be reported upon or forwarded to any third party.

SECTION 1: MIXING AGGRESSION

Mixing aggression occurs to establish a **dominance hierarchy** between **unfamiliar pigs**. Mixing aggression **does not include tail biting** or other vices such as flank or ear biting. Please focus on the **growing and finishing** stages of production when answering questions.

In your opinion, how important is it to reduce the following on your farm in growing/finishing pigs?

	Not important at all								Very important							
Lameness	1	2	3	4	5	6	7									
Mounting	1	2	3	4	5	6	7									
Tail biting	1	2	3	4	5	6	7									
Mixing aggression	1	2	3	4	5	6	7									

Do you avoid mixing unfamiliar growing/finishing pigs as far as is practically possible?

Please tick all that apply

☐	No	☐	Yes, to reduce injuries /stress for the animals
☐	Yes, to avoid spread of disease	☐	Yes, because mixing slows growth rates
☐	Yes, for other reasons. Please Specify:		
☐			

Have any of these people/groups ever emphasised to you the importance of reducing mixing aggression? Please tick all that apply

☐	Veterinarian	☐	Researchers	☐	Wholesale/retail trade
☐	Agricultural adviser	☐	Slaughterhouse staff	☐	Consumer
☐	Other pig farmers	☐	Quality assurance body	☐	Levy body
☐	None	☐	Other. Please specify:		

How much does the opinion of this person/group affect your decisions with regard to mixing aggression?

	Very much						
	Not at all						
Veterinarian	1	2	3	4	5	6	7
Researchers	1	2	3	4	5	6	7
Wholesale/retail trade	1	2	3	4	5	6	7
Agricultural adviser	1	2	3	4	5	6	7
Slaughterhouse staff	1	2	3	4	5	6	7
Consumers	1	2	3	4	5	6	7
Other pig farmers	1	2	3	4	5	6	7
Quality assurance body	1	2	3	4	5	6	7
Levy body	1	2	3	4	5	6	7

Please indicate your level of agreement with the following statements

Between growing finishing pigs	Strongly disagree							Strongly agree	
	1	2	3	4	5	6	7		
<i>Mixing aggression is a problem <u>on my farm</u></i>	1	2	3	4	5	6	7		
<i>A reduction in mixing aggression would create more profit <u>for my farm</u></i>	1	2	3	4	5	6	7		
<i>A reduction in mixing aggression would improve animal welfare <u>on my farm</u></i>	1	2	3	4	5	6	7		
<i>A reduction in mixing aggression would improve my job satisfaction</i>	1	2	3	4	5	6	7		
<i>I am aware of methods to reduce mixing aggression</i>	1	2	3	4	5	6	7		
<i>I or my colleagues have the possibility to make changes in management which would reduce mixing aggression</i>	1	2	3	4	5	6	7		
<i>I or my colleagues have the time available to reduce mixing aggression</i>	1	2	3	4	5	6	7		
<i>I have the financial resources to reduce mixing aggression If financial resources are not your responsibility tick here ☐ and skip</i>	1	2	3	4	5	6	7		
<i>Mixing aggression between pigs is a problem for <u>the industry</u></i>	1	2	3	4	5	6	7		
<i>A reduction in mixing aggression would improve animal welfare in <u>the industry</u></i>	1	2	3	4	5	6	7		

Please indicate which technique(s) you have tried to minimize aggression between growing/finishing pigs. Then, indicate how useful you found those techniques to be.

	Tried (please circle)	Not useful at all							Very useful
		1	2	3	4	5	6	7	
<i>Purposely mixing pigs from neighbouring pens</i>	Yes / No	1	2	3	4	5	6	7	
<i>Odour masking agents</i>	Yes / No	1	2	3	4	5	6	7	
<i>Barriers or get-away areas e.g. adding straw bales</i>	Yes / No	1	2	3	4	5	6	7	
<i>Evening/night time mixing</i>	Yes / No	1	2	3	4	5	6	7	
<i>Distraction material/toys</i>	Yes / No	1	2	3	4	5	6	7	
<i>Pre-weaning socialisation/allowing litters to mix before weaning</i>	Yes / No	1	2	3	4	5	6	7	
<i>Mixed-weight pens</i>	Yes / No	1	2	3	4	5	6	7	
<i>Mix into large groups</i>	Yes / No	1	2	3	4	5	6	7	
<i>Stresnil/azeperone (a sedative)</i>	Yes / No	1	2	3	4	5	6	7	
<i>Other (please specify)</i>		1	2	3	4	5	6	7	

In the near future, how likely are you to

	Not likely at all							Very likely
	1	2	3	4	5	6	7	
<i>Implement strategies to reduce mixing aggression between growing/finishing pigs</i>	1	2	3	4	5	6	7	
<i>Avoid mixing unfamiliar growing/finishing pigs altogether</i>	1	2	3	4	5	6	7	

SECTION 2: STABLE GROUP AGGRESSION

'Aggression in stable groups' refers to aggression between pigs that have not recently been mixed.

Please indicate your level of agreement with the following statements. Please do not include tail biting.

	Strongly disagree					Strongly agree	
Aggression in <u>stable</u> grower/finisher groups is a problem <u>on my farm</u>	1	2	3	4	5	6	7
Aggression in <u>stable</u> grower/finisher groups is a problem <u>for the industry</u>	1	2	3	4	5	6	7

SECTION 3: YOUR FARM

Are you a member of a Quality Assurance Scheme? Please tick all that apply

☐	No scheme	☐	Scottish SPC accreditation	☐	Genesis Quality
☐	RSPCA Assured/Freedom Food	☐	Quality Meat Scotland	☐	Red Tractor
☐	Soil Association	☐	Assured British Pigs	☐	Other, please specify:

How many of the following pigs do you have on your farm, approximately?

Weaners		Grower/finishers		Sows		

How are pigs housed on your farm? Please circle those that apply

Weaners:	Indoor	Outdoor	Combined	Lactating sows:	Indoor	Outdoor	Combined
Growers:	Indoor	Outdoor	Combined	Dry sows:	Indoor	Outdoor	Combined
Finishers:	Indoor	Outdoor	Combined				

On your farm, what is the average group size for grower/finishers?

When do you routinely mix pigs? Tick all that apply

☐	Never	☐	At finisher
☐	At weaning	☐	Before slaughter
☐	At grower	☐	Other, please specify:

SECTION 4: DEMOGRAPHICS

How many years have you worked with pigs?

Year of Birth

Gender

Male	Female	Prefer not to say

Which of the following describes you? Multiple answers possible

☐	Farm owner	☐	Farm worker
☐	Farm manager	☐	Retired
☐	Contract farmer (e.g. bed & breakfast)	☐	Other. Please specify:

Location where the farm is based

☐	England	☐	Wales	☐	Republic of Ireland
☐	Scotland	☐	Northern Ireland	☐	Other, namely:

If you: 1) have any further questions or concerns about this survey or any of its questions 2) would like to be informed of the results of this study or 3) if you are interested in participating in further research into farmers' perception of aggression between pigs. Please contact Rachel Peden at: Rachel.Peden@SRUC.ac.uk or at: [SRUC, Roslin Institute Building, Easter Bush, Roslin, EH25 9RG](#)

Please use the space below to provide additional information or comments

Thank you for taking the time to complete this survey.

Your insight and information are very valuable to us in prioritising our research.

Appendix F

Choice experiment survey (Chapter 6)

Instructions

Introduction

I would like to invite you to participate in a study which **aims to identify practical and cost-effective ways of controlling aggression** when unfamiliar pigs are mixed. This research project is part of my PhD thesis registered at the University of Edinburgh.

If you are willing to participate, you will be asked to complete a questionnaire consisting of two parts; the first involves various **choice questions**, and the second involves some **demographic** questions. In total, completing this questionnaire should not take more than 15 minutes.

If you agree to participate, your responses will remain fully confidential; no personal information will be recorded.

Your participation in this study is completely voluntary and if you do agree to participate, you can withdraw your participation at any time.

Mixing aggression

‘Mixing aggression’ refers to the aggression that occurs when unfamiliar pigs are mixed into new social groups. It does not include tail biting.

Aggression control strategies

A number of methods to reduce mixing aggression have been identified by research. These methods are termed ‘aggression control strategies’.

Aggression control strategies usually involve changes to farm structure, management or husbandry. As a result, they can involve **investment costs** for farmers associated with new equipment and materials. They may also have **ongoing costs** associated with replenishing materials and increased labour requirements. The possible **benefits** of the investment are a **reduction in aggression** and an **improvement in production**. However, aggression control methods differ in these characteristics.

Your choices

You will be presented with **16 different choice questions**. Please note that **the structure of each question is the same**; you will be asked to choose between **three hypothetical**

aggression control strategies. The aggression control strategies are described in terms of **four characteristics** (describing their different costs and benefits), and are **unnamed** and **theoretical**. Please choose the one strategy that you are **most likely to adopt** on your farm. If you do not like any of the aggression control strategies described, you can choose a 'no choice' option.

We know from previous similar studies that people often answer in one way, but behave differently when they have to actually spend their money in a real world situation. When questions do not have real financial implications, people may not really consider the impact of these extra costs. Also, it is easy to be generous when you do not really have to pay for it.

So please respond to each of the following 16 questions **exactly as you would** if you were going to choose an aggression control strategy for **your farm**, and had to pay for your choice.

The following table describes the four characteristics. In the choice questions, you will see different combinations of the characteristic levels.

<u>Characteristics</u>	<u>Characteristic levels</u>
One-off installation cost per pig place (£) <i>This refers to a <u>one-off</u> investment cost for installation of equipment or materials. This cost will be incurred only once.</i>	£1.22per pig place
	£3.62per pig place
	£6.12per pig place
	£9.12per pig place
Running cost per pig lifetime (£) <i>This refers to an <u>ongoing</u> cost for the running and management of the investment. This cost will be incurred for every pig produced.</i>	£0.12per pig
	£0.24per pig
	£0.34per pig
	£0.46per pig
Reduction in lesions (%) <i>This refers to the reduction in lesions in the week following mixing.</i>	10% reduction
	20% reduction
	30% reduction
	40% reduction
Improvement in growth rate (%) <i>This refers to the improvement in growth rate in the week following mixing. After one week the benefit is likely to disappear.</i>	0%
	2%
	5%
	8%

Your choices

Please imagine that you are mixing unfamiliar pigs on your farm.

In the following 16 choice questions, carefully evaluate the three aggression control strategies and **indicate which one you would choose to use on your farm**. If you do not like any of the options, please tick the 'no choice' option.

PART 1. YOUR CHOICES

CONSENT

Please tick here to indicate that you understand the information given and consent to participate

☐

WHICH OF THE FOLLOWING BEST DESCRIBES YOU? *Please*

☐	<i>Farm owner</i>	☐	<i>Farm worker</i>
☐	<i>Farm manager</i>	☐	<i>Retired</i>
☐	<i>Contract farmer (e.g. bed & breakfast)</i>	☐	<i>Other. Please specify:</i>

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 1				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£6.12	£9.12	£1.22	£0.00
Running cost per pig lifetime (£)	£0.34	£0.46	£0.12	£0.00
Reduction in lesions (%) during 7 days after mixing	10%	20%	30%	0%
Improvement in growth rate (%) during 7 days after mixing	5%	8%	0%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 2				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£9.12	£1.22	£3.62	£0.00
Running cost per pig lifetime (£)	£0.46	£0.12	£0.24	£0.00
Reduction in lesions (%) during 7 days after mixing	10%	20%	30%	0%
Improvement in growth rate (%) during 7 days after mixing	8%	0%	2%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option

Choice set 3				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£3.62	£6.12	£9.12	£0.00
Running cost per pig lifetime (£)	£0.24	£0.34	£0.46	£0.00
Reduction in lesions (%) during 7 days after mixing	10%	20%	30%	0%
Improvement in growth rate (%) during 7 days after mixing	2%	5%	8%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 4				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£1.22	£3.62	£6.12	£0.00
Running cost per pig lifetime (£)	£0.12	£0.24	£0.34	£0.00
Reduction in lesions (%) during 7 days after mixing	10%	20%	30%	0%
Improvement in growth rate (%) during 7 days after mixing	0%	2%	5%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 5				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£3.62	£6.12	£9.12	£0.00
Running cost per pig lifetime (£)	£0.46	£0.12	£0.24	£0.00
Reduction in lesions (%) during 7 days after mixing	30%	40%	10%	0%
Improvement in growth rate (%) during 7 days after mixing	0%	2%	5%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 6				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£9.12	£1.22	£3.62	£0.00
Running cost per pig lifetime (£)	£0.34	£0.46	£0.12	£0.00
Reduction in lesions (%) during 7 days after mixing	20%	30%	40%	0%
Improvement in growth rate (%) during 7 days after mixing	0%	2%	5%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 7				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£6.12	£9.12	£1.22	£0.00
Running cost per pig lifetime (£)	£0.24	£0.34	£0.46	£0.00
Reduction in lesions (%) during 7 days after mixing	40%	10%	20%	0%
Improvement in growth rate (%) during 7 days after mixing	0%	2%	5%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 8				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£1.22	£3.62	£6.12	£0.00
Running cost per pig lifetime (£)	£0.46	£0.12	£0.24	£0.00
Reduction in lesions (%) during 7 days after mixing	40%	10%	20%	0%
Improvement in growth rate (%) during 7 days after mixing	5%	8%	0%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 9				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£9.12	£1.22	£3.62	£0.00
Running cost per pig lifetime (£)	£0.12	£0.24	£0.34	£0.00
Reduction in lesions (%) during 7 days after mixing	40%	10%	20%	0%
Improvement in growth rate (%) during 7 days after mixing	2%	5%	8%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 10				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£1.22	£3.62	£6.12	£0.00
Running cost per pig lifetime (£)	£0.34	£0.46	£0.12	£0.00
Reduction in lesions (%) during 7 days after mixing	30%	40%	10%	0%
Improvement in growth rate (%) during 7 days after mixing	2%	5%	8%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 11				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£3.62	£6.12	£9.12	£0.00
Running cost per pig lifetime (£)	£0.34	£0.46	£0.12	£0.00
Reduction in lesions (%) during 7 days after mixing	40%	10%	20%	0%
Improvement in growth rate (%) during 7 days after mixing	8%	0%	2%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 12				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£3.62	£6.12	£9.12	£0.00
Running cost per pig lifetime (£)	£0.12	£0.24	£0.34	£0.00
Reduction in lesions (%) during 7 days after mixing	20%	30%	40%	0%
Improvement in growth rate (%) during 7 days after mixing	5%	8%	0%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 13				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£6.12	£9.12	£1.22	£0.00
Running cost per pig lifetime (£)	£0.12	£0.24	£0.34	£0.00
Reduction in lesions (%) during 7 days after mixing	30%	40%	10%	0%
Improvement in growth rate (%) during 7 days after mixing	8%	0%	2%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 14				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£6.12	£9.12	£1.22	£0.00
Running cost per pig lifetime (£)	£0.46	£0.12	£0.24	£0.00
Reduction in lesions (%) during 7 days after mixing	20%	30%	40%	0%
Improvement in growth rate (%) during 7 days after mixing	2%	5%	8%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 15				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£9.12	£1.22	£3.62	£0.00
Running cost per pig lifetime (£)	£0.24	£0.34	£0.46	£0.00
Reduction in lesions (%) during 7 days after mixing	30%	40%	10%	0%
Improvement in growth rate (%) during 7 days after mixing	5%	8%	0%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

Please remember that if you would not adopt any of the first three aggression control strategies on your farm, you should choose the 'STATUS QUO' option.

Choice set 16				
CHARACTERISTICS	UNNAMED STRATEGY 1	UNNAMED STRATEGY 2	UNNAMED STRATEGY 3	STATUS QUO
One-off installation cost per pig place (£)	£1.22	£3.62	£6.12	£0.00
Running cost per pig lifetime (£)	£0.24	£0.34	£0.46	£0.00
Reduction in lesions (%) during 7 days after mixing	20%	30%	40%	0%
Improvement in growth rate (%) during 7 days after mixing	8%	0%	2%	0%
	☐	☐	☐	☐
Please mark the option you are most likely to adopt				

PART 2. QUESTIONNAIRE

IF YOU ANSWERED 'STATUS QUO' TO ALL CHOICE SETS please let us know why by ticking all relevant boxes:

- ☐ I would not adopt any of the aggression control strategies on my farm
- ☐ I already use aggression control strategies on my farm
- ☐ I don't mix unfamiliar growers/finishers
- ☐ Didn't read the other options
- ☐ Wanted to get finished quickly

Other, Please state:.....

Please indicate your level of agreement/disagreement with the following statements.	Strongly disagree		Strongly agree		
	1	2	3	4	5
<i>When mixing unfamiliar pigs, minimizing aggression is important to me</i>	1	2	3	4	5
<i>Mixing aggression is a problem on my farm</i>	1	2	3	4	5
<i>I avoid mixing unfamiliar pigs wherever possible</i>	1	2	3	4	5
<i>It is possible to control aggression at mixing</i>	1	2	3	4	5
<i>UK standards for pig welfare are sufficiently strict</i>	1	2	3	4	5
<i>The welfare of my animals is important to me</i>	1	2	3	4	5
<i>The welfare of my animals is good</i>	1	2	3	4	5

When do you routinely mix unfamiliar pigs on your farm? Please tick all that apply

☐ Never	☐ At finisher	☐ Other, please specify:
☐ At weaning	☐ Before slaughter	
☐ At grower	☐ Sows	

Roughly how many of the following do you have on your farm at any time?

Weaners:		Finishers:	
Growers:		Sows:	

What is the average group size of growers on your farm?

What is the average group size of finishers on your farm?

How are growing and finishing pigs housed on your farm?

Growers:	☐ Indoor	☐ Outdoor	☐ Combined
Finishers:	☐ Indoor	☐ Outdoor	☐ Combined

When mixing growing/finishing pigs, please indicate your use of the following aggression control strategies. Please circle your answer

<i>Large social group sizes:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Increased space allowance:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Adding extra tryptophan to feed:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Solid visual barriers/ escape areas:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Mixed weight groups:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Mixing at night/ low light levels:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Novel enrichment material:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Tranquilisers (e.g. azaperone):</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>
<i>Avoidance of mixing:</i>	<i>Currently use</i>	<i>Used in the past</i>	<i>Never used</i>

Are you a member of a Quality Assurance Scheme? Please tick all that apply

☐	<i>No scheme</i>	☐	<i>Scottish SPC accreditation</i>	☐	<i>Genesis Quality</i>
☐	<i>RSPCA Assured</i>	☐	<i>Quality Meat Scotland</i>	☐	<i>Red Tractor</i>
☐	<i>Soil Association</i>	☐	<i>Assured British Pigs</i>	☐	<i>Other, please specify:</i>

ABOUT YOU:

Gender:	<i>Male</i>	<i>Female</i>	<i>Prefer not to say</i>

Roughly how many years have you worked with pigs?

Location:

☐	<i>England</i>	☐	<i>Northern Ireland</i>
☐	<i>Scotland</i>	☐	<i>Republic of Ireland</i>
☐	<i>Wales</i>	☐	<i>Other. Please specify:</i>

Thank you for taking the time to complete this survey.

Your insight and information are very valuable to us in directing our research towards demand driven solutions to reduce aggression between pigs.

Appendix G

Cost-benefit analysis survey (Chapter 7)

Estimating the costs and benefits of reducing pig aggression

Researchers have been studying **regrouping aggression between pigs** since the 1970s (aggression that occurs following regrouping of unfamiliar pigs). As a result, several ways of **reducing aggression at regrouping** have been identified. For example, aggression may be reduced by:

- Housing pigs in large social groups (100+)
- Allowing litters to mix prior to weaning

We want to conduct **cost-benefit analyses** to see if these strategies are **financially profitable** for farmers. This cost-benefit analysis involves: (1) calculating the financial **costs** of employing each strategy, (2) calculating the financial **benefits** of employing each strategy, and (3) subtracting the costs from the benefits. If the benefits outweigh the costs, employing that strategy would result in **increased profitability for farmers**.

We would greatly appreciate your help and expertise in estimating the financial costs and benefits of employing aggression control strategies.

What are your current costs per slaughter pig lifetime?

Roughly how many of the following do you have on your farm at any one time?

Weaners:		Growers:	
Finishers:		Sows:	

When do you routinely mix unfamiliar pigs on your farm? *Please circle all that apply*

<i>Never</i>	<i>At finisher</i>	<i>Other, please specify:</i>
<i>At weaning</i>	<i>At slaughter</i>	
<i>At grower</i>	<i>Sows</i>	

What is your average group size for growing/ finishing pigs?

Yes / No

Do you currently apply any chemical additives to feed, water or air e.g. appeasing pheromones, citronella sprays, herbal remedies?

Housing pigs in large social groups

Please imagine that you are going to start housing growing/ finishing pigs in groups of 100 or more on your farm:

What initial investments/changes would you need to make? (e.g. would you need to make any specific changes to your farm?). Please list below.

How much do you estimate that these changes would cost? Please make it clear how these costs are described e.g. per pig or per pen

After the initial investment costs:

Can you envisage any on-going costs associated with housing growing/ finishing pigs in groups of 100 or more? (e.g. increased labour requirements).

How much do you think it would cost? Please make it clear how these costs are described e.g. per pig, per pen or per year

Allowing litters to mix prior to weaning

Please imagine that you are going to start allowing litters to mix prior to weaning:

What initial investments/changes would you need to make? (e.g. would you need to make any specific changes to your farm?). Please list below.

How much do you estimate that these changes would cost? Please make it clear how these costs are described e.g. per pig or per pen

After the initial investment costs:

Can you envisage any on-going costs associated with allowing litters to mix prior to weaning? (e.g. increased labour requirements).

How much do you think it would cost? Please make it clear how these costs are described e.g. per pig or per pen

Please imagine that you see a reduction in regrouping aggression of 50% in your growers/ finishers. What benefits would you expect to see? please circle all relevant responses			
<i>Improved growth rates</i>		<i>Improved feed efficiency</i>	
<i>Reduced skin lesions/injury</i>		<i>Reduced veterinary costs</i>	
<i>Reduced labour requirements</i>		<i>Improved job satisfaction</i>	
<i>Easier animal handling</i>		<i>Reduced mortality</i>	
<i>Other, please specify:</i>			
How much money would you expect to save if you saw a 50% reduction in regrouping aggression in growers/ finishers? Please make it clear how these costs are described e.g. per pig or per pen			
How are growing / finishing pigs housed on your farm? please circle			
Growers:	<i>Indoor</i>	<i>Outdoor</i>	<i>Combined</i>
Finishers:	<i>Indoor</i>	<i>Outdoor</i>	<i>Combined</i>
Are you a member of a Quality Assurance Scheme? Please circle all that apply			
<i>No scheme</i>	<i>Scottish SPC accreditation</i>	<i>Genesis Quality</i>	
<i>RSPCA Assured</i>	<i>Quality Meat Scotland</i>	<i>Red Tractor</i>	
<i>Soil Association</i>	<i>Assured British Pigs</i>	<i>Other, please specify:</i>	
Gender (please circle)	<i>Male</i>	<i>Female</i>	<i>Prefer not to say</i>
Roughly how many years have you worked with pigs?			
Location (please circle)			
<i>England</i>	<i>Wales</i>	<i>Republic of Ireland</i>	
<i>Scotland</i>	<i>Northern Ireland</i>	<i>Other</i>	