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Agent-based modelling in applied ethology: An exploratory case study of behavioural dynamics in tail biting in pigs

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ABSTRACT

Understanding behavioural dynamics in pigs is important to assess pig welfare in current intensive pig production systems. Agent-based modelling (ABM) is an approach to gain insight into behavioural dynamics in pigs, but its use in applied ethology and animal welfare science has been limited so far. We used ABM in a case study on tail biting behaviour in pigs to explore the use of ABM in gaining more insight into emergent injurious pig behaviour and related welfare issues in intensive production systems. We developed an agent-based model in Netlogo 5.1.0 to simulate tail biting behaviour of pigs housed in conventional pens in groups of 10. Pigs in the model started as neutral pigs (not involved in biting incidents), but could change into a biter, victim, or both biter and victim. Tail biting behaviour could emerge when pigs were unable to fulfil their internal motivation to explore. The effects of a redirected exploratory motivation, behavioural changes in victims and preference to bite a lying pig on tail biting patterns were tested in our model. The simulations with the agent-based model showed that coincidence in development of a redirected exploratory motivation can lead to tail biting behaviour in pigs and can explain the strong variations in incidence of tail biting behaviour observed in conventionally housed pigs. Behavioural changes in victims and preference to bite a lying pig seem to be of minor importance in the causation of tail biting patterns. The behavioural time budget of a pig might be an important factor in predisposing pigs to or preventing them from becoming a tail biter or a victim. ABM showed to be useful in analysing behavioural dynamics and welfare issues. An advantage for ABM in applied ethology is the availability of data from empirical studies.

1. Introduction

Current intensive pig production systems are subject to major sustainability concerns, including concerns about pig welfare (Krystallis et al., 2009; Averós et al., 2010). Welfare is a state of the animal of which behaviour is an important indicator (Duncan, 1998). Behaviour is dynamic and the result of a complex interaction between internal factors, such as behavioural needs and characteristics of pigs, and external factors, such as housing conditions and time of day (Jensen and Toates, 1993). Within the EU, fattening pigs in conventional intensive systems are generally housed in rather barren pens, on fully or partially slatted concrete floors, with a space allowance of 1 m^2 per animal or less (EFSA, 2007b). These housing conditions can lead to several welfare issues, such as tail biting and leg injuries (EFSA, 2007a; Averós et al., 2010). Many studies have demonstrated effects of specific adjustments in housing conditions on pig behaviour and other welfare indicators. For instance, housing enriched with rooting materials reduced severe tail biting in pigs (Van de Weerd et al., 2006). To understand the effect of housing on pig welfare, however, it is important to consider the interaction with other internal and external factors and their effect on behavioural dynamics in pigs.

One approach to gain insight into behavioural dynamics is agent-based modelling (ABM) (Railsback and Grimm, 2012). ABM can be used to analyse how pig behaviour emerges from a complex interaction of internal factors and external factors, and how behaviour can develop over time. Although several scientific disciplines, such as ecology and social sciences, commonly use ABM,

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the use of this method in applied ethology and animal welfare science has been limited so far (Asher et al., 2009; Collins and Part, 2013). ABM, however, has potential for use in these fields, since it can include individual variation and social interactions. Furthermore, ABM has the advantage that it can simulate experiments with many combinations of factors and repetitions, which would require many animals and be costly in real life (Asher et al., 2009). The aim of this study is to explore the use of ABM in applied ethology by using a case study of behavioural dynamics in tail biting in intensively housed pigs.

Tail biting behaviour in pigs is defined as biting and chewing (manipulating) the tail of another pig. It can be scaled from gentle to severe and may cause bleeding wounds and infections (Schrøder-Petersen and Simonsen, 2001; D'Eath et al., 2014). Tail biting behaviour can increase over time and lead to a tail biting outbreak (Zonderland et al., 2011b). Tail biting clearly has welfare consequences for the pig that is bitten. It however also has economic consequences for the farmer because pigs with wounds, infections and increased stress might grow less or even die (Schrøder-Petersen and Simonsen, 2001; D'Eath et al., 2014).

The causation of tail biting behaviour is not fully understood and is suggested to be multi-factorial (Moinard et al., 2003). Many risk factors for tail biting behaviour have been identified on commercial farms, including housing conditions, such as lack of rooting materials and high stocking density, and pig characteristics, such as genetic background and poor health (Taylor et al., 2010). As current knowledge on risk factors is not sufficient to control tail biting behaviour under commercial conditions, Schrøder-Petersen and Simonsen (2001) suggested that internal factors and behavioural mechanisms, under influence of external factors, should receive more attention.

Tail biting behaviour is an interesting case for exploring the use of ABM in applied ethology because an agent-based model allows including behavioural mechanisms and interaction with internal and external factors, and can indicate how these can lead to emergent behaviours such as tail biting. We developed an agent-based model on tail biting behaviour following the steps in the modelling cycle described by Grimm and Railsback (2005), which includes formulating research questions, choosing a model structure, implementing the model, and model analysis. In this paper we discuss the difficulties and opportunities of using ABM in applied ethology by presenting the development, analysis and results of the model on tail biting.

2. Theoretical framework on tail biting behaviour in pigs

We used the pattern-oriented modelling (POM) strategy to develop a theoretical framework on tail biting behaviour in pigs. In POM, a model is developed to simulate observed patterns that characterise the system of interest (Grimm et al., 2005; Grimm and Railsback, 2012). If in an agent-based model similar patterns emerge that resemble those empirically observed, that model might contain the right mechanisms for the modelled problem (Grimm and Railsback, 2012). It would then count as an explanation of the causation of these patterns.

2.1. Patterns in tail biting behaviour

Tail biting behaviour entailed on average about 0.07% of the behavioural time budget of a pig in a study with barren housed and tail docked pigs between 5 and 19 weeks of age (Bolhuis et al., 2005). The amount of tail biting behaviour, however, varies largely between studies and between pigs. In a study on barren housed and presumably undocked pigs of Beattie et al. (2005), for example, 43% of the pigs performed tail biting behaviour between 4 and 7 weeks of age, of which 21% spent less than 1.5% of their time on tail biting behaviour and 22% of the pigs spent 1.5% or more of their time on tail biting behaviour.

Tail biting behaviour can develop from a pre-injury stage without visual tail damage into an injury stage with injured and bleeding tails. Bleeding tails can lead to increased restlessness and more pigs engaging in the biting behaviour (EFSA, 2007b). Zonderland et al. (2008) observed an average duration of 7.5 days for development from bite marks to a visible tail wound, but there was a large variation since in a few cases it also evolved within a day. The prevalence of any indication of tail damage in abattoirs ranges on average from 3% in docked pigs to 6–10% in undocked pigs (EFSA, 2007b).

Pigs can be categorised in biter, victim, both biter and victim or neutral (not involved in biting incidents). In barren housed and undocked pigs, 59–67% of the pigs was identified as neutral, 9–10% as biter, 20–29% as victim, and 3–5% as both biter and victim (Brunberg et al., 2011; Ursinus et al., 2014).

2.2. Explaining factors in tail biting behaviour

The model should contain factors that explain the emergence of tail biting behaviour. We considered the following explaining factors in our model: a (redirected) exploratory motivation, behavioural changes in victims and a preference to bite a lying pig. These factors are further described below.

2.2.1. A redirected exploratory motivation

In this paper we focus on the two-stage type of biting behaviour, which is described in most papers (Taylor et al., 2010). Two-stage tail biting behaviour is suggested to start as a redirected exploratory behaviour, in which exploratory behaviour such as oral manipulation is directed to tails. Initially the behaviour causes no visible damage or distress to the victim, but it can turn into more forceful biting behaviour when the skin of a tail is damaged (Taylor et al., 2010). The lack of rooting materials is indicated as the main risk factor for redirecting exploration behaviour to tails of pen mates (Taylor et al., 2010). Although stress is not indicated as a cause in the two-stage type of biting behaviour by Taylor et al. (2010), it seems important in the causation of tail biting behaviour. Not being able to fulfil the behavioural need to explore is thought to be one of the main factors causing stress (Schrøder-Petersen and Simonsen, 2001). Stress might accumulate when multiple factors such as housing conditions, health or feed are suboptimal. Stress can increase the frequency and intensity of normal behaviour patterns, and might change normal behaviour into abnormal behaviour (Schrøder-Petersen and Simonsen, 2001). The question remains, however, why not all pigs in a group, exposed to the same conditions, perform tail biting behaviour if tail biting behaviour is caused by environmental factors or a motivation for oral manipulation (Beattie et al., 2005).

2.2.2. Behavioural changes in victims and preference to bite a lying pig

Since victims show little to no reaction to being tail bitten, the effect of tail biting behaviour on a victim in the pre-injurious stage seems limited (Taylor et al., 2010). Several studies, however, reported an increase in general activity (e.g. Statham et al., 2009; Zonderland et al., 2011b) and changes in behaviour of tail biting victims before tail injuries occur. Future tail biting victims showed, for example, more daily feeding visits than pen mates or control pigs two to five weeks before a tail biting outbreak (Wallenbeck and Keeling, 2013), and a higher level in activity and posture changes than control pigs days before a tail biting outbreak (Zonderland et al., 2011b). This may suggest that victims of tail biting behaviour are affected by tail biting behaviour in the pre-injury stage, even though they do not show outward responses to a tail bite. It might