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Animal agency, animal awareness and animal welfare

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Abstract

In nature, animals need to actively engage with the environment in order to prosper in survival and reproduction. Hence, agency is a central adaptive characteristic of animal life. In this paper, I propose that from the adaptive/functional point of view, four levels of agency can be distinguished, namely passive/reactive agency (animal being behaviourally passive or purely reactive), action-driven agency (animal behaviourally pursuing current desirable outcomes), competence-building agency (animal engaging with the environment to gain skills and information for future use) and aspirational agency (the animal achieving long-term goals through planning and autobiographical reflection). Recent progress in affective neurobiology indicates that each tier of agency is supported by a different type of affective functioning, at least in the case of mammals. Furthermore, the particular agency levels can be linked to distinct degrees of awareness as defined by recent selfhood theories. Based on this coupling between agency adaptive functioning, affective neurobiology and animal awareness levels, I examine several links between animal agency and animal welfare, including the notion of animal boredom, and discuss how animal agency might be promoted in the restrictive frameworks of intensive animal farming.

Keywords: *affective functioning, animal welfare, awareness, boredom, inter-individual differences, ontogeny*

Introduction

How important is agency (operationally defined as inner-motivated behavioural engagement with the environment, cf Steward 2012; Mayr 2013) for the welfare of captive animals? In order to secure a basis for answering this question, I will first examine the phenomenon of animal agency from three perspectives: from the perspective of adaptive functioning, from the perspective of affective functioning and from the perspective of awareness/selfhood. Then, I will outline welfare implications of agency and discuss some developments that may make it easier to implement agency-promoting measures in practical intensive husbandry.

This article is an elaboration of the idea (first published in Špinka & Wemelsfelder 2011) of animal agency as a process that brings competence as a result, with both the process and the resulting altered state of the animal being important for its welfare. Here, I develop the idea in two ways: first, by including also the very low and very high tiers of agency and, second, by linking the agency levels with two other lines of animal welfare inquiry, namely affective neuroscience and awareness/selfhood theory. This effort is a parallel development with the 'effectiveness approach' to animal welfare (Franks & Higgins 2012). While the concept of Franks and Higgins and the concept presented here have much in common, they differ in emphasis (and, thus, can fruitfully complement each other). The effectiveness concept reveals the important distinction between the outcome achievement (value effectiveness), information gathering (truth effectiveness) and being in control (control effectiveness) and posits that the combination of all three (organisational effectiveness) brings the best welfare; the approach presented here highlights the ontogenetic time dimension of the cumulative agency tiers and stresses their link to awareness levels.

Agency from the adaptive point of view

Behavioural interaction with the environment is a defining feature of animals or, at the very least, of post-Cambrian multicellular animals with active complex bodies (Godfrey-Smith 2016). From the adaptive point of view, animals need to behave proactively in order to prosper in surviving and reproducing. If the animal were to behave only in reaction to events in the external environment, it would quickly succumb to other, more active living beings. Thus, from the adaptive perspective, agency is very important.

For the purpose of this article, I will distinguish four tiers on the agency scale: passive/reactive agency, action-driven agency, competence-building agency and aspirational agency. (Table 1). The levels are cumulative in that the presence of a lower level is a precondition for the possession of any higher level. The decisive criterion for distin-

Table 1 The four levels of agency, affective functioning and awareness, developed for the particular case of mammalian biology and psychology.

Behavioural agency levels	Type of overt behaviour	Affective functioning levels	Brain structures mainly involved	Awareness levels
Passive/reactive agency	No overt behaviour except in direct reaction to external stimuli	Homeostatic and sensory affects	Brainstem	Anoetic self: experiencing without knowing/sentience awareness
Action-driven agency	Actively behaving to achieve current outcomes	Emotional action systems	Subcortical (PAG to diencephalon)	
Competence-building agency	Actively behaving to build skills and acquire information for later use	Learning-related emotions	Basal ganglia	Noetic self: knowing/competence awareness
Aspirational agency	Actively behaving in the pursuit of planned and reflected goals	Emotional rumination and regulation, affectively guided planning, intentions to act	Neocortex	Autonoetic self: recalling, planning, intending/ autobiographical and introspective awareness

guishing between the agency levels is the type of behavioural engagement with the surroundings.

The most basic level is passive/reactive agency with the animal either being passive (ie currently expressing no overt behaviour) or reactive (ie the animal displaying only direct behavioural reactions to external events). The reactions could be simple reflexive responses or may involve more cognitively demanding processes, such as perceptual decision-making (eg DasGupta *et al* 2014) that have been previously acquired through higher levels of agency.

The second level, labelled action-driven agency, includes the activity of the animal as it goes around with its daily business to procure food, secure safety, feed its young etc. The form and extent of such agency and its relation to the previously mentioned modes of reactivity and passivity depend on the particular species and current life history situation. For a polar bear (*Ursus maritimus*) mother in the snow den, an emperor penguin (*Aptenodytes forsteri*) during the Antarctic winter or a flea (*Pulex irritans*) pupa, being inactive for weeks or even months is the best behavioural survival and reproduction strategy. On the other hand, a pygmy shrew (*Sorex minutus*) must constantly seek sources of its dispersed invertebrate prey as it has to eat at least once in an hour to survive the winter in Europe, a North American bison (*Bison bison*) needs to spend 40% of the 24-h budget foraging (Rutley & Hudson 2001) and a recently farrowed domestic sow needs to nurse her piglets at least once an hour, on average, for them to sustain good prospects for survival until adulthood.

The third level of agency, labelled here competence-building agency, includes activities that do not serve the purpose of achieving immediate outcomes, but rather enable the animals to gather knowledge and enhance their skills for future use. The different modules of this level of agency include instrumental and social learning, inspective and inquisitive exploration as well as some forms of play and communication with conspecifics. These agency modules are adaptive in that they gather information on and experience various facets of the dynamic natural environments, such as their richness and complexity, stochasticity and openness, resistance and counter-agency (Špinka & Wemelsfelder 2011). The experience and the skills acquired through this type of agency combine to provide the animal with competence, ie the array of tools and strategies that an animal possesses at any given ontogenetic stage to deal with both novel and ongoing challenges (Špinka & Wemelsfelder 2011). For instance, Inglis, Langton and colleagues examined, through modelling, how competence building could proceed through information gathering and through development of novel behaviours in the repertoire of the individual, giving the animal an increased capacity to forage efficiently later (Inglis *et al* 2001) or more flexible responses to environmental change (Inglis & Langton 2006).

The fourth level of aspirational agency, as I call it here, has undoubtedly been crucially important as an adaptive psychological and behavioural module necessary for lifetime success in the complex human societies and is seen as a constitutional element of quality of people's life (Michalos 1985). This level of agency goes beyond acquiring new skills and knowledge. Aspirational agency acts to achieve long-term goals through planning and intentions based on reflected autobiographical history. No doubt rudiments of aspirational agency exist in various non-human animals; however, the current knowledge indicates that in non-human animals, this level of agency is much less prominent than the action-driven and competence-building agency levels.

I do not posit that the four tiers of agency are strictly disjunct strata; nevertheless, this stratification fits the types of adaptive challenges an animal faces in the wild. Passivity and reactivity are the best modes of behaviour in the face of events that the animal cannot influence or predict, such as extreme climate or rare, fast-moving predators. Action-driven agency is best for active achievement of current desirable outcomes while competence-building agency increases the probability of harvesting future benefits. Finally, aspirational agency provides adaptive advantages in a species capable of mentalising own autobiography across several orders of time.

Given their high adaptive potential, it is likely that comparable grades of agency evolved many times in animal

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phylogeny, using differently organised neural circuitries. For instance, rapidly growing experimental evidence documents that many insects behave like cognitive-affective agents when switching between inactivity, exploitation of known resources, individual exploration of known possibilities and various types of social learning (Perry *et al* 2017) yet their brains are many orders smaller (in numbers of neurons) compared to that of vertebrates. Cephalopods, such as octopuses, with their distributed neural systems also employ learning and complex cognition when engaging with their physical and social environment and build their competence through playfully interacting with it (Mather & Dickel 2017). Even cnidarians, such as beadlet anaemonies (*Actinia equina*) with no central nervous systems engage in active fighting over territory, the results of which influence their subsequent bold/shy personality differences (Lane & Briffa 2017). As mammals, we should not succumb to biased presumptions that our class is superior to other taxa in terms of agency complexity, efficiency or importance. Nevertheless, this article will focus on mammalian agency because the neural underpinnings of agency are best known for vertebrates and for mammals in particular.

Agency and affective functioning

At any particular stage of life, an animal needs to employ its passivity and its action and competence-building agencies in a way that is appropriate for the specific situation. What to do now and what to forego for the moment is the important decision-making that determines the behavioural and ultimately the reproductive success of the animal. How is this decision-making proximately accomplished? For mammals, the current understanding of behaviourists and neurobiologists is that behavioural control is achieved through the affective functioning of the animal. In other words, the dynamic complex of affective states is the central piece of the proximate mechanism through which the adaptive functioning is being accomplished.

One of the most comprehensive and empirically well-supported models of mammalian behavioural control is the Affective Neurobiology model by the late Jaak Panksepp (Panksepp 2011a; Panksepp *et al* 2012, 2017). The model distinguishes three gross levels of behavioural control, achieved in the brain through emotion-affective processing (Panksepp 2011a). These include the sub-cortically generated primary process affects, the secondary-process emotions generated through learning processes in basal ganglia and the tertiary affects that arise in the neocortex (especially the frontal lobe) through emotional reflection and affectively guided planning and intentions-to-act.

The primary level consists of sub-neocortically generated primordial affects. These include sensorially (pain, warmth) and homeostatically (hunger, satiation) triggered affects that guide behavioural passivity and reactivity to external and internal events. Furthermore, in the Panksepian model, this level also includes 'emotional affects', ie a distinct set of emotion action systems adapted to guide the behaviour in the critical aspects of survival and reproduction, such as predator and disease avoidance, within-species competition, sexual partner choice and care of progeny. Panksepp identified seven basic emotional systems: RAGE, FEAR and PANIC as negative-aversive emotional dispositions and LUST, CARE, PLAY and SEEKING as positive-appetitive dispositions (Panksepp 2005; Alcaro *et al* 2017). In the behavioural domain, these affects are coupled with the action-driven agency, especially in the form of appetitive modules of the social, reproductive and parental behaviours. At the appropriate time in life history and under specific environmental and physiological conditions, positive emotional systems of LUST, CARE and PLAY motivate the animal to seek, explore and work towards particular trigger stimuli that will bring them closer to the respective consummatory goal. The SEEKING disposition is specific in that it promotes active coping strategies through inciting exploration, seeking and approaching specific sources of stimulation in the environment. The SEEKING inclination and performance acts internally as a reward (Alcaro *et al* 2007), thus being a key driving force behind learning and anticipatory processes. Thus, the SEEKING system may be considered a bridge between the primary- and secondary-process emotions.

The secondary-process emotions, in the Panksepian framework, consist of learning and memory processes that trigger, distribute and combine the primary-process affects adaptively in time and space. The mechanisms of conditioned learning and memory, achieved in the mammalian brain mainly in basal ganglia, add plasticity to the working of primary affects that become associated with conditioned stimuli and novel skills acquired through operant conditioning. Panksepp leaves it open whether these secondary processes are associated with some qualitatively distinct affective feelings. He considers it possible that they may not change the affective quality of the experience, having just the role of "parsing of feelings into diverse temporal and spatial frameworks of individual lives" (Panksepp 2011b). On the other hand, there is evidence both in humans (Topolinski & Reber 2010; Cardwell *et al* 2017) and in non-human animals (Hagen & Broom 2004; McGowan *et al* 2014; Franks 2019; this issue), that the learning processes are accompanied by positive affective feelings of their own kind.

Finally, the tertiary neo-cortically processed 'high' affective functions include reflection and rumination on past emotional states, deliberate decision-making and emotionally guided planning for the future. This level of emotional life relies on integration of lower brain functions into higher brain functions, ie primary emotions and secondary affects are becoming nested within the tertiary processes. The human capacity for these high-level, emotion-cognition integrations is concentrated in medial-frontal regions of the neocortex from where descending neocortical control is exerted through basal ganglia to the thalamus which, in turn, loops back, synchronising outputs back to the neocortex (Panksepp 2011a). It has been documented that some non-human animals possess cognitive abilities, such as episodic-type memory (Ferbinteanu *et al* 2006; Roberts *et al* 2008; Kouwenberg *et al* 2009; Allen & Fortin 2013), decision-making based on future events (Špinka *et al* 1998), intention-type memory (Fuhrer & Gygax 2017) that could serve as

building blocks for tertiary level of emotional life. Yet it remains uncertain what kind and degree of tertiary emotions different species of non-human animals develop during their life and how subjectively prominent these are in proportion to the omnipresent primary and secondary affects.

The Affective Neurobiology model is obviously not the first attempt to link behavioural control to affective experience with the aim of deriving animal welfare implications. For instance, the distinction between the primary- and secondary-process emotions might resemble the Motivational Affective States model by Fraser and Duncan (1998) that makes a distinction between negative affects that motivate the animal to urgently respond to fitness 'threats' and positive affects that incite to take advantage of non-urgent 'opportunities' in order to gain longer-term fitness benefits. In spite of the similarities, the Affective Neurobiology is more developed in two aspects. First, the Panksepian concept accommodates the fact that exactly timed (urgent) actions could be driven by positive affects, such as is the case in courtship and copulation (the LUST system) or suckling the young (the CARE system) while non-urgent long-term affective states could have negative valence, for instance in the form of pessimism acquired through durably sub-optimal environment (Mendl *et al* 2010). In this way, the Affective Neurobiology model goes beyond the too simple threats-vs-opportunities dichotomy of the Motivational Affective States model. Secondly, the classification by Panksepp is firmly based in the specific neurobiological proximate mechanisms while the Motivational Affective States model did not develop this dimension, mostly because the knowledge was not available when the model was constructed.

Agency, affective functioning and awareness levels

Beside the links between adaptive and affective functioning, several theorists (including, among others, Envel Tulving, Antonio Damasio and Jaak Panksepp) posit that the particular levels of adaptive and affective functioning are coupled with different levels of awareness/selfhood. Levels of consciousness/awareness have been discussed in comparative psychology literature under various terms, such as experiential consciousness, self-awareness, or possessing a theory of mind (eg Penn *et al* 2008; Harley 2013; Meunier 2017; Morin 2017). Most of the models agree that there are cumulative degrees or levels of consciousness/awareness, distinguishing from three to six different tiers (Morin 2006). Here, I will use a simple three-tiered model of awareness that fits well with the concept of agency levels presented in this article. Table 1 presents the putative awareness levels as corresponding with the levels of adaptive behavioural agency and affective brain functioning.

At the most basal level of awareness, behavioural reactivity and action-driven agency, accompanied with the homeostatic, sensory and action-linked affects, is associated with a sense of 'core self' (Panksepp *et al* 2012) that may be described as experiencing an "ownership of sensory and behaviour representation" (Philippi *et al* 2012). Tulving calls this level of selfhood the 'anoetic self' (Tulving 2002) and describes it as "experiencing without knowing". For the purpose of this article, the term 'sentience awareness' will be used, making a link to the notion of animals as sentient beings which is a concept widely used in the animal welfare debate. In terms of the time dimension, the sentience awareness resides fully in the present moment.

The next level of awareness is associated, in the behavioural realm, with competence-building agency and, in the affective realm, with memory and learning-related emotions. Tulving calls it the 'noetic self' (Tulving 2002) with main experience of 'knowing'. In this article, the term 'competence awareness' will be used. This label was chosen to highlight the fact that at this level of awareness, the animal experiences a selfhood capable of handling everyday life challenges in an individualised, particular way. This personalised competence arose through the combined skills and knowledge that have been accumulated through the learning and memory processes. This past history of the competence is not part of the awareness but the current competence is.

Finally, the top awareness level is the 'autobiographical awareness' or 'autonoetic self' (Tulving 2002; Panksepp *et al* 2012). At the behavioural level, it is associated with the aspirational agency that works towards long-term goals. The affective processes contributing to the autobiographical awareness include emotional regulation and rumination, affectively guided planning and introspectively conscious intentions-to-act. Combined, these affective processes create the sense and urge of long-term or even lifetime progress, achievement and fulfilment. On the time axis, the autobiographical awareness encompasses the past (in individualised episodic memories), the present (in introspection about the decision-making) and the future (in explicit planning).

Animal agency and animal welfare

How important is agency for animal welfare? The influence of agency on welfare is mostly positive, although some cases of negative impacts will be mentioned later in this section.

The current state of knowledge allows us to identify three ways in which agency can contribute positively to welfare. First, the engagement in action-driven agency and competence-building agency is accompanied by pleasurable emotional experiences and hence contributes to the current welfare. Second, competence-building agency builds capacities and resources for coping with upcoming challenges and thus promotes future welfare. Finally, active and rich action-driven agency and especially competence-building agency, as opposed to agency curtailed by barren environment, may support the development of higher tiers of awareness, thus contributing to a fuller expression of the natural species-typical potential of the animal. With a certain degree of simplification, these three types of agency-driven animal welfare benefits may be linked with the three components of animal welfare as promoted by the various streams of the current theory, namely the affective experience (Duncan 1996), the biological coping (Dawkins 2008) and naturalness (Fraser 2009b).

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As for the immediate affective experience associated with action-driven agency, it can be negatively valenced, for instance, in the case of RAGE-driven confrontation between rival animals (Bartoš *et al* 2007) or when prematurely weaned mammalian young repeatedly call and search for the missing mother under the PANIC motivation (Weary *et al* 2008). Nevertheless, when conditions are conducive or at least permissive for activities associated with any of the LUST, CARE, PLAY or SEEKING action systems, animals will engage in them with gusto and, so the evidence indicates, also enjoy them (Trezza *et al* 2011). Thus, for instance, social play acts as a reward in the sense that animals will work for it (Normansell & Panksepp 1990) and social play also increases opioidergic activity in the 'hedonic hotspot' of the nucleus accumbens (Vanderschuren *et al* 2016). Thus, on the one hand, the prospects for social play stimulate the incentive motivation ('wanting'), thus engaging the animal in rewarding appetitive actions, and, on the other, the actual consummatory engagement in social play triggers the hedonic impact or 'liking' (Trezza *et al* 2011). The CARE system, too, can bring intense positive affects. For instance, interacting with pups is more rewarding for early post-partum rat (*Rattus norvegicus*) mothers than cocaine (Seip & Morrell 2007). And, according to Alcaro and Panksepp (2011), SEEKING is accompanied/driven by a specific positive affective feeling of appetitive eagerness or enthusiastic positive excitement.

The second way through which agency can positively influence animal welfare is through enhanced competence (see Held & Špinka 2011) for this argument applied specifically to play). Animals learn through agency and thus build future capacities to successfully procure 'what they want' which is a central part of their welfare (Dawkins 2008). Both the central levels of animal agency contribute to these benefits. Competence-building agency, by definition, is designed to equip the animal with better knowledge about its *umwelt* and more developed capacities to match it. Action-driven agency, although primarily serving the achievement of specific consummatory goals, also offers many opportunities for learning beneficial associations and successful actions. For instance, maternal contact, social play behaviour and sexual behaviour all have a learning component as they elicit associative learning to predict which social cues lead to consummatory success (Trezza *et al* 2011) and provide opportunity for motor and social skills training (Chaloupková *et al* 2007; Pellis & Pellis 2009). In sum, agency builds higher competence that enables the animals to procure more positive affects of sensory, homeostatic and action-related origin.

The third, most putative, welfare contribution of agency is through enriching the selfhood/awareness of the animal. As an animal builds its competence through successful action-driven agency actions and especially through competence-building agency, it not only increases the probability of successful actions that generate positive affective states (see the previous paragraph), but also its awareness gets fuller and more richly structured. In the terminology of Tulving (2002), as experiencing gets complemented with knowing, the anoetic self matures in the noetic self and, perhaps, at least in some cases, builds a basis for the autonoetic self. Or, as Philippi *et al* (2012) put it, the memory and learning processes support the inclusion of autobiographical and introspective elements into the core self of personal agency. Now the question arises as to whether a fuller and richer self (awareness) is of animal welfare relevance.

In humans, theorising and research on human quality of life and happiness does not stall at 'pleasurable life' but also include 'engaged life' and 'meaningful life' in the equation (Seligman *et al* 2005). A recent development in this trend is the 'effectiveness' theory of human motivation developed by Higgins (2012) which posits that human well-being is highest when the person enjoys 'organisational effectiveness', ie when the ability to achieve desirable outcomes is combined with the capacity to establish what is real and managing what happens. During the last decade, it has been proposed that similar concepts could be applied to animal welfare. Thus, Yeates and Main (2008) included 'engagements' and 'realisations' as modules of positive welfare, Špinka and Wemelsfelder (2011) proposed that the welfare value of engaging with challenges resides both in the process of agency and in the resulting competence and Franks and Higgins (2012) directly transferred the effectiveness concept from human well-being to animal welfare. The common theme of these approaches is that it matters for an animal's well-being how the individual feels about its competence *vis à vis* its complex and dynamic *umwelt*. From the perspective developed in this article, a more developed competence is coupled with a fuller and richer awareness. If we embrace 'naturalness' as an integral component of animal welfare, following prevailing public opinion and the line of thought pursued by Fraser (2009b) and Rollin (2007), then a stronger competence-building and (if present) aspirational agency will make a substantial contribution to animal welfare of captive animals. This is because the higher levels of agency allow a more complete development of the animal's natural capabilities (Nussbaum 2018). In other words, animal agency may be seen as a very central part of the animal's nature that is valuable on its own and not just through its contribution to the affective well-feeling or through its operational utility for healthy bodily functioning.

The last two positive effects of agency on welfare have an ontogenetic dimension, that is, the agency at a given ontogenetic stage brings benefits that are spread from the present into the future. However, the ontogenetic dynamism between agency, competence and awareness can also cause deterioration in welfare. This may, specifically, be the case when agency is first instigated to develop through a stimulating and supportive environment but later curtailed by putting the animal into a more barren and/or restrictive living place (Brajon *et al* 2017). In their ontogenetic development, individual animals might commit themselves to a certain level of agency that has been 'promised' by the richness of the rearing environment. Heightened agency may equip the animals with competences that are useful in a variable envi-

ronment but, at the same time, may paradoxically make them ill-prepared to live in a barren environment where reduced agency fits better the general paucity of stimulation and change. This phenomenon deserves sustained research attention in terms of its mechanisms, ontogenetic dynamism, adaptive function and ethical implications.

Relationship between boredom and agency

Boredom, compared to agency, is a notion with a longer trajectory in animal welfare thinking and research (Wemelsfelder 1984, 1993; Burn 2017; Meagher 2019; this issue). Boredom can be characterised as a state caused by a discrepancy between high general motivation for stimulation and a lack of actual stimulation (Burn 2017) or, alternatively, as a situation where limited environmental opportunities/challenges do not allow the animal to use its skills through a meaningful behaviour (Špinka & Wemelsfelder 2011). Boredom can be detected behaviourally by heightened proclivity of the animal to approach all kinds of stimuli, ranging from rewarding to (normally) aversive ones (Meagher *et al* 2017). Boredom is an adaptive emotional and behavioural state that can serve two basic functions. First, it incites the animal to seek the places and situations where currently the interesting and important events are happening, such as where other animals socially interact or where information could be gathered about potential food sources. Second, it could prompt learning through which individual lifetime niche diversification can occur (Burn 2017). The niche diversification means that each animal gradually focuses on different opportunities and creates distinct ways of procuring resources such as food or shelter or bonding with social partners. From the adaptive perspective, boredom and agency are mutual mirror aspects: the immediate adaptive function of boredom has its counterpart in the action-driven agency and the niche-building function of boredom corresponds to the competence-building agency. In relation to animal welfare, the concept of agency is suitable for investigations of the positive aspect of the animal's behavioural engagement with the environment (Lawrence *et al* 2018) while the notion of boredom covers the negative aspect. From the perspective of lifetime welfare, long-term boredom may be one of the causes of shorter lifespan in barren-housed captive animals (Meagher 2019; this issue), while competence-building agency may have the opposite effect through equipping animals with competencies that make them successful at solving future challenges. From the comparative perspective, species may differ in their innate boredom susceptibility along with their differences in intelligence and/or dietary and habitat specialisation/opportunism (Burn 2017; Meagher 2019; this issue). In this article, I argue that the different levels of agency are variously important for different species according to their life history, habitat and niche. Thus, the phenomena of boredom and agency parallel each other across several levels of biological functioning and welfare concerns.

Nevertheless, agency seems to encompass positive animal welfare issues that reach beyond its counterpart role to boredom. First, the acknowledgement of passive/reactive agency level as a frequent adaptive behavioural state (including cases such as hibernation, resting, sleep or sickness inactivity) maintains that, depending on the species and the current life-history and physiological state, doing overtly nothing and/or just reacting to external stimuli may be the most positive welfare state of an animal for short or long periods of time. Second, the cumulative scaling of agency begs the question as to whether the quality of life also scales with the complexity of awareness as associated with the grading agency levels.

Possibilities to promote agency-related welfare: examples for farm animals

Problems with restricted agency and the resulting compromised welfare are present in all classes of captive animals, including lab, pet, zoo, work and farm animals. The fast-growing acknowledgement of the seriousness of this situation has led to genuine progress in many specific cases. For instance, the zoo literature contains many examples of species-tailored modifications of the captive conditions that allow the animals to exercise their agency through learning or solving problems (eg McGowan *et al* 2010; Wagman *et al* 2018). Nevertheless, I will focus on farm animals in this final section as they are the most numerous class and also because the possibilities for change are hindered by tight economical margins dictated by voracious and bargain-chasing consumption habits of the global consumers in combination with large-scale, high-throughput marketing strategies of the various commercial stakeholders.

How feasible is it to implement opportunities for agency in intensive farm animal husbandry in the near future? There might be production benefits associated with heightened agency, but on the whole they may not outweigh the costs of implementing the opportunities *en masse*, thus hindering uptake of such measures by the industry. Most previously confined farm animals, such as dairy cows, pregnant sows or laying hens are now group-housed yet their opportunity to choose or even shape an individually fitting physical and social environment remains very limited. Nevertheless, I see two fields in which the production and welfare perspectives on agency may coincide.

The first is the mostly uncharted role of individual preferences in animal welfare. It is well established that individual animals of one and the same species differ in their preferred physical environment (Larsen *et al* 2017; Taylor *et al* 2017), in how actively, boldly and attentively they interact with it (Reale *et al* 2007) and also in their boredom proneness (Meagher 2019; this issue). A study in laying hens demonstrated that individuals of the same species and category have different environmental preferences and that the individual welfare is, on average, the best in the individually preferred environment (Nicol *et al* 2009). Thus, there is no optimal environment for everybody but rather individually distinct optimal environments. This indicates that if the

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animals were given an opportunity to individually choose between differently tuned environments (eg through setting environmental gradients or giving animals a possibility to regulate the environment), their agency may lead to a better individual fit with the environment, and hence higher overall welfare. For instance, individual laboratory mice (*Mus musculus*) tested by Gordon *et al* (2000) differed by at least 5°C in the preferred floor temperature under otherwise identical conditions. Utilisation of individual choice by the animals might also be attractive for the farmers, if it enables the animals to live in micro-environments that fit them well and thus support their individual health, production and reproduction. The individual choice may be given either in the permanent living environment, or temporarily, such as around parturition (Rorvang *et al* 2018).

The second field where agency could be utilised to enhance welfare in farm animals is social life. In contrast to the barren and unchanging physical environment, the social environment could be, even under intensive husbandry conditions, dynamic and self-structuring and thus supportive for agency and its positive effects. For instance, cows in dynamic groups on a dairy farm interact preferentially with partners that they know from earlier times in ontogeny, thus indicating that they value long-term relationships (Gygax *et al* 2010; Gutmann *et al* 2015). Individual social preferences, intense animal communication and other socially structured phenomena, such as emotional contagion (Špinka 2012; Goumon & Špinka 2016) may combine at the group level into novel emergent properties, such that group-level personalities can develop akin to those that have been documented in insect societies (Jandt *et al* 2014). Thus, through appropriate shaping of group composition, farm animals can be given sufficient social space in which both action-driven agency and competence-building agency will be possible or even stimulated.

Given the economic and spatial limits in large-scale intense animal farming, implementation of agency-friendly environments in mainstream global animal husbandry may seem a distant possibility. Nevertheless, the development might be speeded up through progress in sensor technologies, in monitoring techniques and algorithms, such as bioacoustics monitoring (Schön *et al* 2004; Vandermeulen *et al* 2015), image analysis (Nasirahmadi *et al* 2015; Nilsson *et al* 2015; Guzhva *et al* 2016,) or thermal imaging (Naas *et al* 2014) as well as in hybrid systems that integrate animal behaviour with IT technologies and robotics. Such a high-tech approach has so far been aimed mostly at detection of health and welfare problems (Matthews *et al* 2016) but widening the focus to include positive welfare is highly desirable (Lawrence *et al* 2018). Better and deeper understanding of animal agency in each particular species, including its different levels and inter-individual differences, will be a necessary pre-condition for any such progress.

Animal welfare implications

With increasing attention to positive animal welfare, promoting agency in captive and domestic animals is becoming an important topic in animal welfare thinking, science and practice. However, supporting agency is not a straightforward task. Our current knowledge indicates that animal agency cannot be understood as a unitary or unidimensional behavioural capacity. Rather, considerations about its adaptive function, evidence about its neuro-affective underpinnings and current ideas about its link to animal awareness all point to agency as a faculty that spans several levels of complexity. Both conceptual and empirical research into animal agency is still in its infancy and hence deserves resources and effort in order to fulfil its promising role in the complex realm of animal well-being.

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