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Increasing farm animal welfare by positively motivated instrumental behaviour☆

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ABSTRACT

Rewarded instrumental learning leads to the association of an environmental cue with the positive result of the own activity. Instrumental behaviour includes motivation for a specific reward, anticipation of its successful acquisition and positive appraisal. In this paper, we present theoretical and empirical evidence for the potential of an advanced type of cognitive enrichment, which enables farm animals to develop instrumental behaviour as a factor increasing the animals' experience of well-being. Using the cognitive approach the particularities of positively motivated instrumental behaviour are discussed considering existing experimental results from farm animal studies. Further we outline specific conditions and possible consequences when enrichment allowing instrumental behaviour is integrated in farming practice. It is concluded that this approach meets major requirements for a better emotional animal welfare. In addition it may have the potential to enhance production quality in animal husbandry.

1. Introduction

Intensive farm animal housings are typically characterised by few offers to display various behaviour. Besides affecting welfare in general this results frequently in behavioural maladaptations (Boyle et al., 2002; Guy et al., 2002; Van De Weerd et al., 2005, 2006; Rodenburg and Koene, 2007). For example, vulva or tail biting in pigs can even have economic consequences. Hence any means that are able to promote active behaviour and give animals the opportunity of controlling their environment might not only increase welfare but also reduce behavioural problems occurring in intensive husbandry. Forms of instrumental learning may be suitable ways to enrich domestic animals' environments providing them with 'cognitive enrichment', a term coined by Milgram (2003) in a study testing aged dogs' learning capacity. Rewarded instrumental learning has already been applied successfully to improve care, management and welfare of zoo animals (Carlstead and Shepherdson, 2000; Schapiro et al., 2003). Likewise experiments on learning behaviour with various farm animal species using visual (Sappington and Goldman, 1994; Rehkämper and Görlach, 1997; Langbein et al., 2004), auditory (Ernst et al., 2005; Wredle et al., 2006) or local (Hagen and Broom, 2004; Lee et al., 2007) cues have demonstrated their ability to adapt behaviour in order to be rewarded.

The motivation to do certain things and to avoid others, i.e. the expected or experienced appraisal of a stimulus or situation, is basically innate and shaped by evolution with the goal to increase biological fitness (Dawkins, 1990, 1998; Panksepp, 1994). The resulting behaviour frequently has a strong internal drive to be performed (behavioural 'need', cf. Jensen and Toates, 1993), as for example, chewing on a substrate in pigs (Van De Weerd et al., 2006). In addition it is clearly advantageous if during individual development, rules and regularities of the environment are detected in order to find cues and items which may increase fitness (McLean, 2001). Finally even

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these cues then may gain a value like the associated unconditional appraisal (Spruijt et al., 2001; Van Der Harst et al., 2003).

Hence, it is reasonable to assume that each behaviour, stimulus, or environmental condition allowing or promising a fitness-increasing consummatory act is labelled by positive affects (Cardinal et al., 2002). On the proximate level, in an individual, such evolutionary selected affects direct behaviour and behavioural adaptation, i.e. learning. In humans, at least, positive affects result in pleasant feelings (LeDoux, 1995). If animals are to some degree aware of emotions as representations of their affective inner states the respective feelings may be similar (Boissy et al., 2007).

Consequently, cognitive enrichment based on instrumental learning directed to a highly motivating consummatory act may have the capacity to increase animal welfare. It may initiate positive emotions and feelings during the detection of environmental contingencies. When instrumental behaviour is firm, the anticipation and prediction of behavioural consequences after the successful and rewarded action is likewise labelled by positive emotions (Boissy et al., 2007). In this paper, we highlight the particular theoretical and practical conditions under which instrumental learning as a cognitive enrichment may enhance farm animal welfare. We further discuss the conditions under which this type of enrichment may have a realistic chance to be implemented in commercial farming.

2. Theoretic background

The idea to use instrumental behaviour in farm animal housing in order to improve welfare bases mainly on theoretic concepts of reward-directed learning paralleled by mesolimbic activation, maintenance of motivation, successful coping, predictability and control of the environment. It is attached to the concept of boredom defined as a chronic lack of opportunities for environmental interaction and challenge (Wemelsfelder, 1993) and further to the model of behavioural control by a combination of stimulus-response-like behaviour and learning (Toates, 2004).

Classically, positive instrumental learning is described as a process where the probability of a behaviour, e.g. pressing a lever, is increased by a resulting positive reinforcement, e.g. dispensing palatable food (Skinner, 1984). Additional discriminatory stimuli, typically visual or auditory cues, may be introduced to indicate particular locations or times at which the behavioural act will result in a rewarding outcome. After sufficient trials the contingency between the cue and the appropriate rewarded action becomes firmly associated.

It is easily conceived that this type of operant adaptation to an environment could have benefits for the animals and also for a variety of farm practices. However, instrumental learning is not a passive adaptation but includes several intrinsic traits. In the following we will highlight those ones which have an impact on emotions and, hence, have the potential to modulate welfare of the animals.

2.1. Motivation

'Motivation' is a well-established notion to give an answer to asking for the reason why an animal performs a particular behaviour (Broom and Fraser, 2007). It is suggested that natural selection has favoured negative and positive affect to trigger motivational processes (Fraser and Duncan, 1998). According to the cognitive approach, which seems particularly adequate when animal behaviour and welfare shall be viewed within a single conceptual framework (Dantzer, 2002), internal motivational variables, somatic sensory inputs, the own behaviour and external stimuli are represented simultaneously within the neural network of the brain (Damasio, 1998). In the connectionist view, which is most suited for understanding the situation in animals, the inner representations are realised by spatial–temporal interactions of neurons in a non-symbolic and not necessarily conscious way (Singer, 1998, 2002).

Internal representations allow goal-directed appetitive behaviour where the goal is represented as a specific state within the neuronal network (Jensen and Toates, 1993; Mendl and Paul, 2004; Niv et al., 2006), correlated with a maximum state of well-being, cf. metabolic and hormonal homeostasis, proper exterosensory input, absence of environmental distractors and of negative somatic input. The brain evaluates the consequences of the own behaviour in relation to the goal and determines 'error signals' indicating deviations from the expected result of an action (Dickinson and Ballaine, 1994; Thelen and Smith, 1996). In this view, motivation results from the presence of an error signal in particular dimensions of the internally represented entity (that means everything which is represented in the brain of an individual). The brain organises and, during learning, reorganises the inner representations of sensory inputs and actions and their temporal contingency such that the inner state of equilibrium shifts in a positive direction (Chambers et al., 2007). As stated above such shifts are accompanied by positive emotions, i.e. they enhance well-being.

Being a result of completely internal actions of the brain's neuronal networks, motivation can neither be observed directly nor can it be generated by external influences. It may, however, be modulated by external stimuli, but still under the control of strictly internal rules and variables (Ullman, 1980; Maturana, 1999). Motivations may fluctuate (e.g. in a circadian or annual manner), occur in chains where the next link largely depends on the execution of a previous consummatory act, they may be ordered hierarchically, or may be in conflict with coincident other motivations. The motivational strength to perform instrumental behaviour can be judged indirectly by behavioural demand functions (Dawkins, 1983; Matthew and Ladewig, 1994). This has already been formulated in the 'matching law' of behavioural activity (Baum, 1981) that says that the frequency of an activity relative to all others matches its reward value relative to all others.

Whether an instantaneous stimulus or a situation is a motivating challenge or can be ignored is determined autonomously by the animal according to the actual state of the internal neuronal variables. A certain stimulus or situation may be challenging for one individual but not for another. For the same individual, a stimulus may be sometimes a challenge and sometimes not. Hence the terminological distinction between intrinsically and extrinsically motivated behaviour does not seem completely adequate because, as mentioned, each motivation is intrinsic in the sense, that it depends exclusively on internal states how an animal will react to a stimulus (Hughes and Duncan, 1988). However, we go along with speaking of intrinsically and extrinsically reinforced behaviour because then just the spatial position of the reinforcer is localised. The representation of the external reinforcer is always intrinsic to the brain and does not only depend on the physicochemical character of a given reinforcer but also on experience and individual short- and long-term preferences.

According to the definitions given by Tarou and Bashaw (2007) intrinsically reinforced behaviour, that is behaviour released exclusively by internal representations of the own bodily state including brain states, has an increased probability to occur again after its execution, as e.g. stereotypies. Extrinsic reinforced behaviour, that is behaviour which is released by internal representations of both the bodily state and extrinsic conditions, is characterised by a rewarding consequence of behaviour in the environment. The presence of the external stimulus increases the likelihood that the behaviour recurs, as is observed during instrumental behaviour.

Motivation is the most important factor when considering instrumental learning as a cognitive enrichment. In order to be effective enrichment has to address motivations which are salient because of their evolutionarily shaped importance. This holds particularly when the animals have to be motivated to learn autonomously (see below). However, the intrinsic character of motivation will always result in a residual uncertainty if, how, and when an individual farm animal will react to a challenging task.

2.2. Activity of the neural reward system

The neural mechanism by which instrumental behaviour is rewarding is largely based on mesolimbic activity, i.e. dopaminergic input from the ventral tegmental area to the nucleus accumbens in the basal forebrain (Spruijt et al., 2001; Boissy et al., 2007). This system is activated during appetitive behaviour when, by the organism's own activity, a motivating goal is being approached and predicted (Martin and Ono, 2000), independent of the specific kind of the reward (Salamone et al., 1994; Meredith and Totterdell, 1999; Robinson et al., 2005). The refinement of behaviour during the behavioural shaping phase is reinforced by mesolimbic activity directed to the behavioural refinement itself, i.e. the reduction of the error relative to expectation (Schultz, 2001) and the following consummatory act. Mesolimbic activation is rewarding by itself as indicated by numerous experimental studies which have demonstrated vigorous self-stimulation in this brain area (Fiorino et al., 1993), corroborating the view that the activation of a neuronal network involved in the representation of successful approach to a rewarding goal increases experienced well-being. Hence, in farm animals successful instrumental learning as a cognitive adaptation activating the mesolimbic system can be an effective source of well-being. This activation will be triggered by the increase of instrumental performance, that is control over the task, and prediction of the reward.

2.3. Control and predictability

Control, that is knowledge of the consequences of actions, is an important factor of welfare. Its loss has been convincingly detected as a major cause of distress (Bassett and Buchanan-Smith, 2007). Based on broad experimental evidence (reviewed by Bassett and Buchanan-Smith, 2007) the acquisition of control is a considerable enrichment factor (Sambrook and Buchanan-Smith, 1997; Laule and Desmond, 1998). It is evident that this is of particular value if it relates to environmental factors for which salient motivations exist.

Gaining control is tightly coupled with an increase in predictability enabling the animal to be prepared for the event (Badia et al., 1979). When talking about predictability the time-range of prediction has to be considered, however. If animals are not enabled to act quickly for being rewarded as expected, passive waiting for an anticipated reward can be stressing (Bloomsmith and Lambeth, 1995) due to loss of control. Hence, the positive affective value of a long latency anticipation of a rewarding item might be questionable. It is surely different from the anticipation of a reward that can readily be achieved after an appropriate action. This latter type of anticipation, where reward is obtained after a short time while the animal is active in a goal-directed manner, can even increase the appreciation of the following consummatory act (Spruijt et al., 2001; Dudink et al., 2006).

Learning instrumental behaviour generally includes three consecutive phases: first, the detection of a discriminatory stimulus that is contingent to the primary motivating reward, second, shaping of behaviour to get access to the reward, and finally complete control over the task. In the last two phases, anticipating reward after appropriate instrumental behaviour has a positive emotional effect (Martin and Ono, 2000; Spruijt et al., 2001).

Though the anticipation effect in the last phase is stable and requires attention to discriminate the occurrence of stimuli indicating the possibility of accessing the predicted reward the animals may eventually become 'over-experienced' so that a more or less automated reactive behaviour may develop (Meehan and Mench, 2007). Then, some new learning may be appropriate to sustain the positive effect of cognitive enrichment. This can be achieved, for example, by changing the conditioned discriminatory stimulus or by introducing a further conditioned behaviour (e.g. variable or fixed ratio lever pressing) to the initial one. In both cases it has been demonstrated that farm animals (goats and pigs) 'learn to learn' as they acquire new but similar tasks with an increasing learning speed (Langbein et al., 2007; Puppe et al., 2007) while predictability becomes slightly reduced in order to keep some degree of ongoing challenge.

Taken together, it is tempting to conclude that control and predictability, as major elements of welfare, may be improved considerably by equipment allowing instrumental behaviour.

3. Instrumental learning and behaviour as an enrichment factor in farm practice

Farm animals regularly learn about specific traits and characters in their environment even in common intensive housing systems (reviewed by Wechsler and Lea, 2007). Simple non-associative habituation might be involved in decreasing resistance towards human staff, for example, when animals are guided to another place. Associative instrumental learning occurs when animals quickly recognise and remember the location of feeding and drinking sites and learn to discriminate social traits of group members. But the simplicity of these tasks, and the small degree of control in most of them, cannot be expected to increase emotional welfare considerably. This may be reached if equipment and situations are provided that particularly address the conditions outlined in the preceding section.

However, there are some special aspects with applications of more sophisticated learning setups when they have to be integrated in commercial farming practice.

3.1. Autonomous learning

On farm, instrumental learning as a cognitive enrichment will usually be self-controlled by herded animals. Management could be automated and integrated into commercial procedures. Supplying the animals with motivating reward – usually feed or water in farm practice – may in addition divert the animals from maladaptive, stereotypic behaviour and supports agility (Puppe et al., 2007).

Advanced equipment for autonomous instrumental learning integrated in home pens of animals has been designed for gerbils (Meier et al., 1998), dwarf goats (Franz, 2001; Langbein et al., 2004), pigs (Ernst et al., 2005) and dairy cows (Wredle et al., 2006). The access was free for each animal of the group unless the equipment was occupied by another animal. In most cases cue presentations, dispensing reward, and animal registration were done automatically by a computer.

Such devices offer several advantages which as well concern the learning procedure as the animals' motivation to learn. Particularly in social species individual learning can be assessed without disturbing and stressing the animals by separation of the group. When the animals are enabled to visit the learning equipment voluntarily a large number of individuals can be trained quasi-simultaneously. In addition, inadvertent cuing by an experimenter is avoided (Langbein et al., 2006, 2007). Finally, and equally important, if spontaneously visiting the equipment the animals train when they are most motivated to work for the supplied rewarding reinforcer. Thus, self-controlled instrumental learning occurs when the animals have a similar and adequate state of motivation.

The animals can learn autonomously to discriminate specific sensory signals aimed to guide them according to a desired management routine. Pigs and cattle, for example, have been trained successfully to follow an acoustic summons to a particular feeding place (Ernst et al., 2005; Wredle et al., 2006). When, for the purpose of active management, animals are trained to follow summons this is on the expense of free access to equipment but it challenges the animals' sensory attention and readiness to learn so that the characteristic features of cognitive enrichment are still present.

However, appetitive behaviour towards reward may decrease considerably when satiety is reached. Then, the motivating value of the primary rewarding stimulus may decrease to zero or even may become negative (Solomon and Corbit, 1974). One way to maintain the instrumental behaviour of farm animals, where the incentive usually will be food or water, could be changing the quality of the reward occasionally. However, the probably more convenient approach is a proper quantification of reward given with each successful behaviour, so that complete satiety is reached only after having performed the required number of instrumental actions.

3.2. Peculiarities in farming application

Learning should be facilitated by paying attention to preferences and peculiarities of the species, as in detail reviewed by Wechsler and Lea (2007). Some rewards may work with one species but less or not at all with another and some discriminative cues may easily be associated with a particular reward in one species while failing in another.

The ability and readiness for instrumental learning may also depend on individual traits. Usually, younger animals will develop new behaviour resulting from learning more readily than older ones (Milgram, 2003). As well, animals who have had some experience with environmental variability including somehow hidden rewards may be more easily adapting to new enrichment factors (Wechsler and Lea, 2007). Hence, they may particularly be prone to subject themselves to goal-directed instrumental learning.

The training of naïve animals should take place in steps. They have to be shaped for actions on the button or lever if such releasers of reward are integrated in the learning equipment (Langbein et al., 2004). Instrumental learning can be facilitated when the animals are subjected to a preceding Pavlovian conditioning where the discriminative cue is paired with the same reward at the same location (Ernst et al., 2005; Galarce et al., 2007).

During the learning phase, re-grouping or a change of housing environment should be avoided since this may interfere with the steady acquisition of instrumental performance (Baymann et al., 2007). After learning has been completed and the animals cope well with the cognitive demand a change of housing environment still may interfere with the performance for some time (Langbein et al., 2006).

For all applications in farm practice it is important to make sure that all animals who are grouped together have a sufficient access to the devices for instrumental behaviour. The number of devices for instrumental cognitive enrichment must be sufficient to provide all animals of a given group with the regular opportunity to apply what they have learned. If they have to wait too long for the next access to the equipment and are rewarded too rarely this may attenuate motivation. In addition, a low number of places for reward can considerably increase the tendency of the animals to stay in the vicinity so that mutual obstruction may occur (Wredle et al., 2006), including competition and agonistic behaviour.

If the animals shall be guided individually to a device or place an individual discriminative cue has to be assigned to each animal of a group. Hence, enough (=number of animals) cues must exist that can be discriminated. The sensory ability for discrimination, e.g. of sounds, more than the capacity of learning is the critical component when larger animal groups are considered. The animals will learn to associate just their specific acoustic summons with reward but they must be able to recognise it out of plenty of others. Generally discriminative stimuli in any sensory domain should be as simple as possible and easy to discriminate by the animals. When the way of individual calling shall be pursued it will be a topic of creative cue design and applied behavioural research to find solutions and to outline the limits of a species' capacity for sensory discrimination.

4. Discussion

The intention of providing captive animals with environmental enrichment is to improve health, reduce abnormal or stereotypic behaviour, and increase the range of normal behaviour (Mench et al., 1998; Baymann et al., 2007). A further aim of enrichment is increasing environmental complexity and thereby satisfying motivation to perform specific appetitive behaviour (Carlstead and Shepherdson, 2000).

New external conditions and objects that are potentially important for survival will reasonably induce the motivation for inspection. It may be a threat or, for example, a food source. If however such objects have been scrutinised with the result of being useless for internal equilibrium, they will be recognised as unimportant and no longer motivating to activity in the future. Consequently, with simple forms of enrichment like chains or plastic balls, the animals mostly lose interest after just a few days (Jones, 2001; Tarou and Bashaw, 2007).

We consider instrumental behaviour rewarded with essential resources to be significant for increasing welfare. Adopting the term allostasis, which was coined for hormonal adaptation by change (McEwen and Wingfield, 2003) instrumental learning can be understood as a sustained change within the brain's neuronal networks. An error signal with respect to a momentary goal then results in behaviour in order to cope successfully with a challenge. As a consequence, successful instrumental learning that is reinforced by reward may be viewed as a process of allostasis and re-adjusts the internally determined equilibrium. A welfare concept based on allostasis (Korte et al., 2007) claims that welfare is at risk both, when the learning capacity of an animal is under- or overtaxed.

Due to better control over the environment and a predictable result with a high hedonic value instrumental learning and behaviour primarily address the psychological cognitive and emotional aspect of welfare. The cognitive approach to animal behaviour and learning does not only include information gathering, storage and processing (Shettleworth, 2001) but also the representation of inner states which are the basis of evaluative processes (Dantzer, 2002). The results of these evaluations direct the animal's choices in a given situation towards increasing fitness, a shift that is accompanied by positive emotions (Boissy et al., 2007). The evaluations in addition allow to anticipate the consequences of actions based on experience (Spruijt et al., 2001).

In accordance with the concept of judgment shift (Harding et al., 2004; Mendl and Paul, 2004) regularly experienced positive affects can add up to a generalised persistent good mood (Matheson et al., 2008). Corroborating the increase in psychological welfare we have found that, compared to pigs living without enrichment, pigs displayed less fearful behaviour in an open field when they were fed by a cognitive enrichment equipment that called the animals individually to feeding with an acoustic summons (Puppe et al., 2007). In the same animals effects on the immune system and a better wound healing occurred (Ernst et al., 2006). The latter results may indicate better general health, which at least in part may be provoked by a better emotional state. Similar effects of a positive psychological state on health have been described in humans (Edwards and Cooper, 1988; Esch and Stefano, 2004). In another experiment (Langbein et al., 2004) we presented dwarf goats a computer-based learning device which offered them drinking water as a reward. Their heart rates increased in a first visual discrimination task, but then decreased in similar tasks using different cues, which was interpreted as an evidence that the goats had been exposed to a positive challenge.

The evolutionary approach saying that the successful acquisition of resources increasing fitness goes along with positive affects (Fraser and Duncan, 1998) provokes research on coincident behavioural and physiological markers. Such markers may have some absolute value as references. In order to avoid circular reasoning the parameters have to be gained and validated in contexts which clearly and agreeable are related to positive affects. Instrumental behaviour fulfils this requirement to a large degree if it results in a significant reward (cf. Baum, 1981; Esch and Stefano, 2004). Then, behaviour and physiology coinciding with instrumental behaviour can be investigated experimentally.

Boissy et al. (2007) reviewed suitable parameters for this approach in animals, as for example anxiety, exploration, play, and stereotypic behaviour. Such parameters are able to demonstrate a biased mood as a consequence of the repeated positive experience when successfully predicting and controlling their environment (Matheson et al., 2008). Physiological effects of instrumental behaviour can be revealed in addition by measuring heart-rate activity (Von Borell et al., 2007) which can be recorded non-invasively. Another valuable parameter to investigate effects of food rewarded instrumental behaviour are *post-mortem* studies of opioid receptors in brain areas related to 'liking' (Berridge, 1996; Olszewski and Levine, 2007). A further, more indirect parameter is probably general health since positive emotional states have been correlated to positive effects on the immune system in humans (Edwards and Cooper, 1988).

4.1. Open questions

There is further need of research answering some important questions before advanced instrumental learning devices in farming will be applied as management elements or enrichment. The effects of cyclic relocations, as frequently occurring in farm management routines, on the stability of instrumental behaviour has to be investigated thoroughly. Do the animals remember the rewarded stimuli as well as how to act on the device after weeks or months in another environment? Can the animals make immediately use of the device in another environment? To what degree are farm animal species able to generalise over various subtypes of devices? What are gentle, animal friendly strategies to motivate an animal to leave a device after having been rewarded (in order to make it free for the next)? How many different reward-signalling stimuli can be discriminated by a farm animal species? What are the formal criteria for a good distinguishability in important sensory domains? Preferentially such research should be done under the conditions of practical farming in order to avoid too many influences by untypical group sizes or environments. Finally, the net effect on welfare improvement must be demonstrated (e.g. animal health, frequency of mutual aggressions and stereotypies).

4.2. Implications for practical husbandry

Supposed that the integration of rewarded instrumental behaviour in largely automated management procedures is possible, and technical equipment for a herd of some size is not exceeding economic limits, an increase of animal welfare in intensive farming can be expected. When such advanced cognitive enrichment is used for active animal management, i.e. individual calling to a feeding or milking facility, aggressiveness can be reduced since only in the called individual the discriminative cue releases instrumental behaviour while it is neglected by the other members of the herd.

Such improved management systems could be successful particularly in sow and dairy cow husbandry. In species which in nature find their food in small portions, e.g. pigs while rooting, regular and frequent individual calling keeps the animals busy when their feed credit is distributed over hours and may reduce boredom, aggressiveness and maladaptive behaviour that can lead to mutual injuries. Dairy cows could be called in groups to milking parlours or individually to automatic milking systems. For horses housed in box stalls cognitive enrichment, e.g. a screen offering visual patterns that indicate access to a (small) portion of oats, may prevent stereotypies, as for example, crib biting or weaving.

In practical application attention has to be paid to some points mentioned above. Animals should not be raised in a cognitively impoverished environment before subjected to instrumental learning if it shall succeed quickly. During learning, re-grouping and relocation should be avoided. When establishing instrumental cognitive enrichment the animals have to be carefully monitored, particularly in the instrumental learning phase, when they are not already familiar with the equipment. This has to be done in order to ensure that positive effects in all phases of adaptation exceed non-intended negative ones (Wechsler and Lea, 2007).

5. Conclusion

Cognitive enrichment based on instrumental behaviour may supply animals with challenging situations, which they can solve successfully using cognitive skills. It includes regular motivating rewards the access to which can be predicted and controlled and, therefore, meets major requirements to enhance emotional welfare. If individuals quickly associate a discriminative cue to the reward it can be concluded that they positively appraise the situation. Instrumental learning could be integrated in already existing management practices of precision livestock-farming. It has the potential to reduce unwanted behaviour and to reinforce wanted behaviour, for example, undisturbed calm feeding and moving at an intended time to particular sites.

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