From operant learning to cognitive enrichment in farm animal housing: bases and applicability

G Manteuffel*, J Langbein and B Puppe

Research Institute for the Biology of Farm Animals (FBN), Unit Behavioural Physiology, Wilhelm-Stahl-Allee 2, 18196 Dummerstorf, Germany
* Contact for correspondence and requests for reprints: manteuff@fbn-dummerstorf.de

Abstract

This study has its basis in recent findings by our own and other laboratories and proposes a type of rewarded operant learning that seeks the detection of discriminatory cues as a cognitive enrichment in intensive husbandry systems. This type of cognitive enrichment has the ability to activate the intrinsically-rewarding mesolimbic brain axis when an animal acquires successful strategies to cope with environmental demands. It provides animals with the opportunity to develop positive affects through control of their environment and the anticipation of consummatory reward. If true animal welfare is considered more than simply the absence of stress and harm, provoking better affective conditions may be a suitable way of increasing the well-being of intensively-housed animals. Recent research with elaborated operant learning equipment, under experimental and quasi-commercial conditions, revealed better health, reduced boredom and less maladaptive behaviour as potentially practical advantages. A number of the issues regarding the transfer of this suggested form of cognitive enrichment to large scale, commercial farming are discussed.

Keywords: *animal welfare, cognition, farm animals, learning, motivation, reward*

Introduction

Modern, intensive farm animal husbandry is characterised typically by housing environments that seek to fulfil production requirements to the detriment of many of the needs defined in the 'Five Freedoms' formulated by the Farm Animal Welfare Council (FAWC) (as reviewed by Webster 1998). Farm animal species have well-developed sensory and cognitive abilities (Ginane *et al* 2002; Croney *et al* 2003; Nicol 2005; Della Chiesa *et al* 2006; Désiré *et al* 2006) therefore, merely satisfying their needs in terms of adequate food, shelter and space would appear insufficient in terms of welfare. The assertion that animals are capable of experiencing negative affects means that, by the same token, we should also concede positive emotions, and this assumption is supported by Burgdorf and Panksepp (2006). Therefore, the promotion of welfare should include regular experience of positive affects that may add up to a generalised, persistent good mood (Boissy *et al* 2007), in accordance with the concept of judgment shift (Harding *et al* 2004; Mendl & Paul 2004). It has been recently demonstrated that such shifts do not only occur in the negative direction as a result of stressful environments (Paul *et al* 2005, Bateson & Matheson 2007) but also in a positive sense as a consequence of well-designed, environmental enrichment (Matheson *et al* 2008).

Environmental enrichment is a means of improving animal health or physiological function, decreasing abnormal or stereotypic behaviour, and increasing the range of normal behaviour in confined animals (Mench *et al* 1998; Baymann *et al* 2007). Generally, attempts to enhance farm animal environments are based on inanimate forms of enrichment which would set out to increase environmental complexity and satisfy the motivation to perform specific appetitive behaviours (Carlstead & Shepherdson 2000). The main disadvantage of the mostly simple forms of inanimate enrichment is, however, the fact that the animals quickly lose interest as habituation to novel objects usually occurs after only a few days (Platt & Novak 1997; Jones 2001; Wells 2004; Tarou & Bashaw 2007).

Well-designed, environmental enrichment should present objects or situations that act successfully and with a foreseeable rewarding outcome. Such anticipation is developed after the association of an indicating stimulus to a significant event. In a complex environment, an animal has to recognise and select such discriminatory stimuli before they can be associated and gain affective valence. This requires a degree of cognitive environmental processing, including elements of sensory discrimination, attention and appraisal (Désiré *et al* 2002; Paul *et al* 2005; Boissy *et al* 2007).

In recent years, specific forms of positive operant training (POT) have been introduced in zoos, to not only control the animals and facilitate specific management routines (Reinhardt 2003), but also as a form of enrichment (Laule & Desmond 1998; Kuehn 2002). Initial investigation has revealed positive long-term effects of POT on behaviour and welfare beyond the acute training period (Carlstead & Shepherdson 2000; Laule *et al* 2003; Milgram 2003; Hiby *et al* 2004). Milgram (2003) termed such cognitive challenges, integrated in the normal housing routine, 'cognitive enrichment'.

Cognitive enrichment (CE) by operant discriminatory learning

Simple forms of operant learning are already common in farm animal housing (Kilgour *et al* 1991; Wechsler & Lea 2007), eg animals learning to operate feeders or nipple drinkers. However, the animals adapt very quickly to the equipment and develop rather automated behaviour. In order to maintain a greater level of challenge, the demands on sensory perception and attention should be higher. Animals are, in general, able to cope well with such cognitive and sensory challenges (Nicol 1996).

Cognitive enrichment (CE) of farm animal housing should be thus defined as the ability to elicit perceptive processes for operant learning of discriminatory cues which lead eventually to a better active control of the environment. It demands behavioural coping with a sustained cognitive and behavioural challenge. The prerequisite is that coping be rewarded by an item that is supplied by the CE setup and appreciated by the animals. Extrinsic reinforcement tends to have longer-lasting attractive effects because, by definition, behaviour is reinforced by the chance to acquire a rewarding item supplied externally, ie by the environment (Tarou & Bashaw 2007). In the initial phase of coping with the challenge, however, intrinsically-reinforced, transient exploratory behaviour is necessary in order to detect the rewarding properties of the CE equipment (see Figure 1).

In order for environmental enrichment to be effective, motivation has to be maintained over a long period (Meehan & Mench 2007). However, motivation may decrease to zero or even be reversed after a consummatory act that completely fulfils the needs (Solomon & Corbit 1974). In order to overcome this effect, the amount of reward can be reduced to only a partial fulfilment after each successful action at the CE equipment. This is not an unnatural condition, since species which usually forage for small portions of food, ie most of our common farm animals, tend not to be well adapted to one or two substantial meals per day (Montaudouin & Le Pape 2005). Consequently, it has been recommended by these authors to deliver feed in small and in some way hidden portions throughout the day.

It has also been argued that a decreasing response rate to an external rewarding stimulus may be an effect of habituation (McSweeny *et al* 1996; reviewed by Tarou & Bashaw 2007). Despite the fact that this is only seen to occur with very frequent presentations of the reinforcer and, as such, is preventable via a reduction in the number of stimulus repe-titions, habituation may also be counterbalanced by changing the property characteristics of the reward (Melville *et al* 1997). With CE, decreasing motivation or habituation can, thus, be largely avoided by a reasonable number of stimulus presentations or with variable reward items, indicated by the same cue stimulus which has been paired with various reinforcers during learning. The latter type of learning induces behaviour directed to the rewarding site (Garlace *et al* 2007).

Cognitive skills include arousal, some type of sensory information gathering and dealing with this information in a goal-directed manner (Shettleworth 2001). The motivation for and the anticipation of the final reward is the source of activating arousal. During the process of learning, the conditioned cue becomes associated with the reward and induces learned appetitive behaviour (Hughes & Duncan 1988). In most animals, operant learning does not occur without a reinforcing final consummatory act (in a broad sense, including the elimination of an aversive stimulus), and learned appetitive behaviour also does not appear without this reinforcement. Accordingly, in cognitive theories of behavioural control, inner representations of an animal's state is the basis for discriminatory decisions (Hughes & Duncan 1988; Mendl & Paul 2004; Boissy *et al* 2007) resulting in the animal's selection of behaviour that increases the hedonic value of the inner state (Niv *et al* 2006). Such that, if, in a learning paradigm, a discriminatory cue is detected as being regularly contingent with a subsequent positive affect and its inner representation as a positive emotion, the cue itself may gain a positive value (Spruijt *et al* 2001).

The neural mechanism by which cognitive activity is rewarding has its basis in mesolimbic activity, ie dopaminergic input to the nucleus accumbens in the basal forebrain (Spruijt *et al* 2001; Phillips *et al* 2003; Boissy *et al* 2007). Together with other limbic structures, such as the hippocampus, it is activated during appetitive behaviour when, by the organism's own activity, a motivating goal is being approached, independent of the specific type of reward (Carelli & Deadwyler 1994; Salamone *et al* 1994; Hemby *et al* 1997; Meredith & Totterdell 1999; Robinson *et al* 2005). This activation, by itself, is reinforcing as indicated by numerous experimental studies which have demonstrated vigorous self-stimulation in this area of the brain (Fiorino *et al* 1993; Chang *et al* 1997).

CE, as it is understood here, is based on self-controlled operant learning of group-housed animals living in their common home pen. The pen contains learning equipment, which is attractive to the animals as it dispenses a reward after a trained action. In the initial phase, the animal detects a discriminatory stimulus that is contingent to the primary motivating reward. In the second, behaviour to gain access to the reward is refined and, in the final phase, this behaviour becomes a routine (Figure 1). As stated above, the refinement of behaviour during the second shaping phase is intrinsically rewarded by mesolimbic activity directed to the reduction of behavioural errors (Schultz

Figure 1
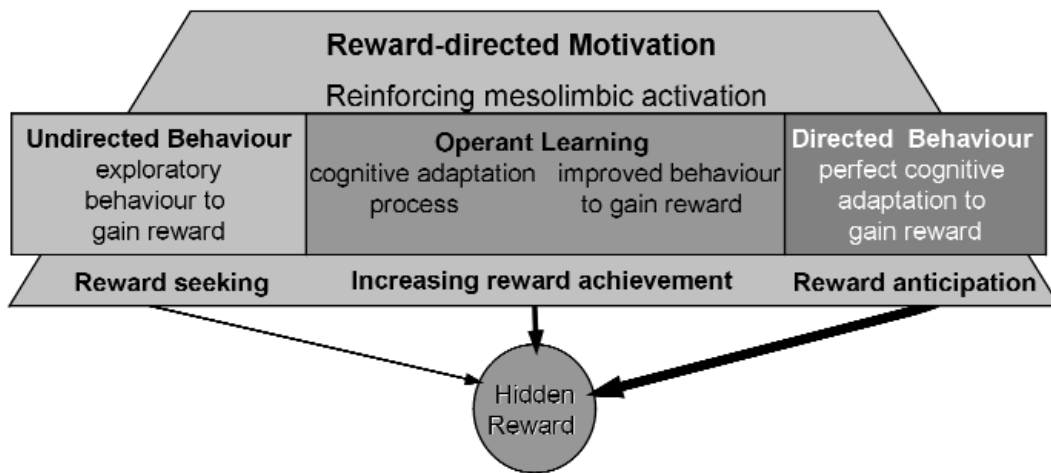
The different phases of an animal's dealing with cognitive enrichment. In each phase the behaviour is driven by motivation for a primary reward (eg feed) which is not directly accessible but can be reached after increasing competence of behaviour (indicated by more bold-face arrows) due to cognitive adaptation.

2001) and the following consummatory act. In the course of this phase, the animals gain control over the challenge. In the last phase, anticipating reward after behaving in accordance with the learned routine, has a positive emotional effect (Dudink *et al* 2006). Here, the animals have full control of the environmental challenge.

Although the anticipation effect in the last phase is stable and requires attention to discriminate against the occurrence of stimuli indicating the possibility of accessing the predicted reward, the animals may eventually become 'over-experienced' such that a more-or-less automated reactive behaviour may develop (Meehan & Mench 2007). In this instance, some new learning may be appropriate to make the effect of cognitive enrichment more sustained. This can be achieved, for example, by changing, to some extent, the conditioned discriminatory stimulus or by adding a further conditioned behaviour (eg variable or fixed ratio lever pressing) to the initial one.

Experimental approaches to CE in farm animal housing

Learning studies in farm animals have mostly used animals that have been separated from their herds (eg horse: Hanggi 2003; lambs: Désiré *et al* 2004; heifers: Hagen & Broom 2004). In such artificial situations, social animals, however, may be stressed by losing contact with group members. Nevertheless, indications of positive emotional reactions have been found in these experimental situations when the effects on heart rate, play behaviour or arousal, in the course of increasing control over the environment, have been examined systematically (Désiré *et al* 2004; Hagen & Broom 2004).

Devices aimed at including CE in standard farm animal housing, have been tested experimentally in our group. The respective studies have been carried out on dwarf goats and

pigs. Dwarf goats had to acquire drinking water via the discrimination of visual shapes presented in a fully-automated, computer-controlled device which was integrated into the home pen which they shared with pen mates (Langbein *et al* 2004, 2006; Baymann *et al* 2007). Goats could access the apparatus at all times but only one goat at a time could gain entry to the compartment with the device.

The animals mastered how to obtain water from the learning device (shape discrimination waterer [SDW]) after being shaped for button pressing to release water. The design of self-controlled learning, with no restriction regarding the number of trials at the SDW, enabled each animal to gain sufficient water, independent of the individual learning performance. This is due to the fact that with a four-choice discrimination task there was a 25% chance of hitting the correct button. Consequently, animals which were yet to master the technique simply had to increase the number of trials in order to obtain sufficient water. This, in turn, accelerated the speed of learning by increasing the number of trials at the SDW (Langbein *et al* 2007).

The general tension (ie stressed vs relaxed) during the learning process was judged based on heart-rate parameters while animals were resting in their pen (Langbein *et al* 2004). While the heart rate (HR) was increased tonically when the animals were confronted with a discrimination task for the first time, this effect vanished during subsequent tasks, indicating variable effects on HR depending on the level of familiarity goats had with the situation. A significant influence of the task and the interaction between task, and time within the task, on heart-rate variability (HRV) was found. This suggests long-term changes in vagal activity, dependent upon learning performance, over the course of a task and in consecutive tasks. This effect is

Figure 2

A pig at a call feeding station (CFS). Also note the resting pig at the right margin which has not been called.

thought to be the result of increased relaxation after animals have developed full control of the cognitive demand presented by the SDW.

We also tested the effects of relocating well-trained animals to another pen, equipped with the same type of SDW (Langbein *et al* 2006). Despite the new pen being virtually identical to the original, animals revealed a significant, yet transient, drop in performance at the SDW in the new pen; initial performance levels returning after one day. This effect of ambient environment on cognitive performance most likely resulted from a shifting of attention to the new environment since learning devices were identical for both pens.

The social rank of the animals in the pens did not correlate with individual learning success and memory in the SDW as long as the animals remained in their groups and pens (Baymann *et al* 2007). However, when the animals were regrouped, low-ranking goats required more trials in order to reach a given learning criterion.

In pig housing, a CE device that governed the feeding management was used. For growing pigs housed in groups of eight, the pen was equipped with four call feeding stations (CFS). These summoned the pigs individually via a

jingle (Ernst *et al* 2005). The CFSs (Figure 2) included a feed dispenser, a loudspeaker for calling and a pushbutton for depression with the nose disk.

Each animal underwent pre-training to an individual jingle in an initial, Pavlovian conditioning phase. The sound was played immediately prior to the dispensing of feed while pigs visited an arbitrary CFS, spontaneously. Recently, work with rats has shown that transfer from Pavlovian cue conditioning to subsequent operant learning occurs (Garlace *et al* 2007) such that operant responding motivation increases after previous Pavlovian conditioning to the cue.

In the following phase, an animal could only acquire feed when it followed the summons of the CFS calling with the jingle that was attributed to the individual. Since each individual in the group had its own particular jingle, each animal also had its own discriminatory stimulus. In a later phase, additional pushing of a button had to occur. To avoid weakening of the motivation, the operant work for obtaining the reward was increased stepwise, ie the animals had to push the button repeatedly with an increasing fixed ratio to get a portion of feed. An effect of calling with an individualistic jingle was that only the invited animal moved to the CFS. The remaining conspecifics, which had never associated that particular sound with feeding, continued with their normal behaviour and, as a result, there was no disturbance while feeding.

After several weeks under the CFS regime, animals underwent an examination of their immune systems and their capacity for wound healing. IgG antibody concentrations were higher and wound healing found to be faster in experimental compared to control animals which were fed conventionally (Ernst *et al* 2006). In addition, they developed less aberrant behaviour (belly nosing). In a changed environmental context (open field) they displayed significantly reduced signs of anxiety (Puppe *et al* 2007). As a side-effect, certain meat quality parameters also improved (Fiedler *et al* 2005). This was probably due to an increased locomotor activity.

Taken together, the experiments with learning equipment in home pens, in which the animals were kept in groups, show that different species, such as goats and pigs, are readily able to adapt to the demands of cognitive enrichment and control the environment by behaving appropriately. Those animals' physiological parameters can be carefully interpreted as indirect measures of improved welfare; probably induced by increased activity, behavioural success and reduced boredom.

A roundly similar approach, as described with pigs above, was conducted by Wredle *et al* (2006). Although the main aim of their experiment was not to supply cognitive enrichment but to guide cows to an automatic milking system, the method used involved learning a particular behaviour which was eventually rewarded. Cows were supplied with individual, sound-emitting boxes fixed to their collars. In the training phase, a conditional sound stimulus was manually emitted by a human trainer whenever the cow was within the milking unit and feed was dropped into the feeding trough. In the following phase, those animals which did not

visit the automatic milking system voluntarily were called by the acoustic signal of the sound box.

Approximately half of the cows reacted to the calling and the proportion of correct responses was more than four times greater in cows which were indoors and, hence, close to the milking unit offering the feed. Possible reasons for this were given by the authors as a reduced motivation for grazing animals to move the greater distance to the milking station or as a contextual effect, since the cows had been trained indoors. Further, as only one milking station was supplied, cows had to occasionally wait for entry to the system when it was occupied by another individual. In cows with a low rank, this could lead to extinction when they were never or only very rarely rewarded after responding correctly. The experiment, thus, points to some difficulties which can arise with cognitive enrichment in practical farming.

How can CE be integrated into commercial farm housing?

Although animal welfare can be regarded as a value in itself, in order to make it easier to integrate CE in commercial farm housing, improvements for the farmers should also be demonstrated. While there may be little resistance to integrating enhanced cognitive enrichment in zoo-keeping (Schmidt & Markowitz 1977; Kuehn 2002; Reinhardt 2003) there may be more in commercial farming. Unless obliged by law, cost restrictions may prevent improvements. However, the integration of CE in farm animal housing might stand a genuine chance if benefits, eg in animal health and/or product quality, can be demonstrated. In large, intensive animal plants already with highly-automated management systems and little human-animal interaction, the net cost-benefit ratio can be expected to be at least neutral or even positive through easier management and, most importantly, increased animal health. The latter can be expected to arise both as a direct and an indirect effect of CE. A direct effect could be mediated by the influence of a sense of well-being on the immune system (Edwards & Cooper 1988; Esch & Stefano 2004). The indirect one has several aspects. The most obvious may be less maladapted behaviours as a result of less boredom. This will divert animals from many of the behaviours directed at pen mates and, as a result, reduce considerably the probability of injuring them. This might already have been achieved, to a certain extent, with simple environmental enrichment equipment, like the 'Edinburgh Foodball' (Young *et al* 1994) which addresses exploratory and cognitive behaviour and delivers feed reward. The return for farmers, however, can be intensified when CE becomes well integrated into management routines and, as described above with the CFS, individual animals can be guided to feeding at separate times and each animal is able to feed undisturbed without stress. However, management routines should avoid combinations of routines, such as mixing and relocation, with changes in the learning task because of the negative effects this can have on learning and memory, particularly in low-ranking animals (Baymann *et al* 2007).

It has been argued that drinking or feeding in a device separated from the herd can be detrimental to welfare in farm animals. It is beyond the scope of this paper to discuss this in detail but the fact that feeding tends to occur at the same time in animal groups when feed is supplied at troughs, does not necessarily imply that animals do so because they like it. It may well be an effect of competition for restricted amounts of feed.

Technically, CE concepts could be added to pre-existing modern management and supply systems which already have the capability of recognising individual animals and deliver feed or water. They can be an integrated part of modern, automated, whole farm managing systems with individual animal surveillance as a further element of precision livestock farming.

Attention has to be paid to certain peculiarities, though. CE equipment must be specifically adapted to a species' ability to cope with environmental challenges. This implies that sensory cues consider possible sensory limitations, actions can be performed easily and the offered reward is genuinely motivating. Usually, younger animals will develop new behaviour resulting from cognitive activity more readily than older ones (Milgram 2003). The technical equipment and its computational control have to be reliable in order to avoid uncertainty in reward delivery which can result in frustration. Also, the construction of the device has to be such that the animals are, indeed, challenged cognitively and cannot 'tunnel' the task by simple, non-cognitive behaviours (eg 'stealing' the reward of others). The adaptation procedures must be carefully designed and possibly include several steps (eg Pavlovian pre-conditioning whereby the animals can associate the cue with the delivery of reward when voluntarily visiting the dispensing site), so that the animals can train without deprivation or any loss of economical performance. Commercial systems will only be successful if training can be managed automatically and with very little need for human supervision (Wechsler & Lea 2007).

Economical constraints will probably lead to a tendency for large groups of animals to only be supplied with few, or even simply one, source of reward. This confers two drawbacks that will counteract any benefits. Firstly, as is generally the case with low animal-to-feeding place ratios, animals will have a temporally-restricted access. If they are rewarded too rarely and have to wait too long for the next opportunity to act for reward, it is likely to pose a negative counterbalance to any positive motivation. Secondly, a low number of places for reward can lead to a considerable increase in the tendency for animals to be close to the site, such that they hinder each other (Wredle *et al* 2006) and competition and agonistic behaviour may occur. Hence, the animals must be motivated to leave the location after having received their reward. To overcome these difficulties, there has to be, at the very least, a reliable automatic registration that signals the occupation of the rewarding site to the control unit, so that during this period no other animal is actively attracted.

Linking CE with luxury behaviour seems possible in principle. However, the motivation for luxury behaviour may be variable and transient in contrast to the non-elastic demand for feed or drinking (Matthews & Ladewig 1994) so that the integration in on-farm management procedures seems difficult. Hence, even relatively low-cost equipment may not be very attractive to commercial farmers.

Discussion

Supplying animals living in commercial, intensive housing with the opportunity to explore more sophisticated environments, to assume control of them, and to anticipate a rewarding outcome to their activities seems an effective way of reducing boredom with its negative consequences on well-being, health and behaviour. The increase of predictability and controllability is the main reason why CE can be expected to enhance the welfare status of the animals. Based on broad, experimental evidence (reviewed by Bassett & Buchanan-Smith 2007) the acquisition of control, that is to learn about the consequences of actions, is a considerable enrichment factor (Scott 1990; Sambrook & Buchanan-Smith 1997; Laule & Desmond 1998). Gaining control usually has a close association with an increase in predictability. The prediction of positive events, eg access to feed, activates psychological and physiological systems. The mental expectation of a pleasant sensory experience is paralleled by preparatory autonomic reactions, eg salivation, which may increase the hedonic value of the reward (Bassett & Buchanan-Smith 2007).

The importance of the active control of access to a reward has been shown to come at fixed times in captive animals waiting for food where the delay between expectation and reward may be long. In horses, monkeys and captive bears, stereotypies have been observed to occur frequently when animals are waiting to be fed or for other rewarding regular events for which appearance is out of their control (Cooper *et al* 2000; Waitt & Buchanan-Smith 2001; Montaudouin & Le Pape 2005). It could be concluded that long, passive waiting for an anticipated reward can be a source of stress (Bloomsmith & Lambeth 1995) due to loss of control. Hence, the positive affective value of a long, latent anticipation of a rewarding item might be questionable. It differs, surely, from anticipation of a reward that is readily obtainable after an appropriate action. This latter, short-term anticipation can even increase the appreciation of the following consummatory act (Spruijt *et al* 2001; Dudink *et al* 2006).

Short-term predictability, induced by reliable cues, may be of particular benefit to welfare if the cues are presented at random times and locations (Shepherdson *et al* 1993) because it prevents stereotypic and possibly stressful (Bloomsmith & Lambeth 1995) food-anticipatory activity occurring with fixed-feeding schedules. The reliability of the contingency of the cues with reward does not only guarantee that a reward can be expected. The absence of the cue likewise signals 'safe' periods (Carlstead 1986) (see also Figure 2), during which animals can rest, free from disturbance from the potential necessity to compete for rewarding items with group mates. This safe resting can even be enhanced when the animals are called to rewarding sites with an individual summons that does not activate other individuals.

Learning, as such, is a common phenomenon in animal husbandry and farm animals are readily able to use this ability to cope with environmental demands (for a review, see Wechsler & Lea 2007). They are adept at detecting locations and types of stimuli and resources that are rewarding to them and, in this way, learn about their environment. Given that the rewards offered are genuinely motivating (ie address the innate appetitive drive of the individuals of a species), technical equipment that demands cognitive processes mimics the challenges of natural environments without imitating nature. It would appear virtually impossible to supply animals in intensive housing, in keeping with 'natural' environments and, hence, well-designed technical solutions that integrate progressive management and CE represent a suitable approach for the future which may allow an increase in animal welfare without compromising the farmers' economical constraints.

CE equipment has to take into account species-specific peculiarities in order for the desired goal to be reached. It has to be adapted to each species' cognitive abilities, natural explorative behaviour and specific reward properties in order to be effective and not overtaxing. Therefore, the design has to be tested carefully before it may be applied on a broad scale. Such tests should not only check the animals' abilities to cope with the offered demands but also look for indications of improved welfare. As a direct test, one could observe the behaviour of satiated animals. If CE was rewarding by itself, then they could, at least occasionally, visit the CE equipment to gain the rewarding item (eg feed) without displaying consummatory behaviour after being successful or could prefer being rewarded by the CE over free access to feed (Neuringer 1969). However, reports on the occurrence of 'contra freeloading' behaviour in non-primate mammals (Inglis & Shepherd 1994; Young 2003) are ambiguous. Such behavioural preferences may depend, to some extent, on strains or races of a species and have been discussed in terms of the acquisition of control and knowledge of the environment under the condition that immediate needs are fulfilled (Inglis *et al* 2001; Schütz *et al* 2001). Moreover, when CE is linked with important management procedures (eg feeding), frequent contra-freeloading behaviour is not desirable since the animals would then occupy the equipment.

An indirect way of demonstrating the positive effects of CE could be based on emotional shifts. If the experiences with CE are positive, the animals should display more signs of a pleasant disposition than controls which receive the same reward without preceding cognitive efforts. Such indicators have been reviewed by Boissy *et al* (2007). For example, the animals should be less anxious and more explorative, play more frequently and display less stereotypy. Further, they can be expected to display positive emotional bias as a consequence of the repeated positive experience when successfully controlling their environment (Matheson *et al* 2008). Another indirect way to confirm positive effects of

CE can be pursued if adequate and representative physiological measures are developed. Measuring parameters of heart-rate activity may be one suitable way (reviewed by von Borell *et al* 2007). Respective reactions can be recorded easily and non-invasively, in which longer durations or more frequent occurrences of heart-rate parameters indicating positive emotional states would be valuable indicators of positive experiences. A further indirect parameter could be general health since positive emotional states have been correlated to positive effects on the immune system in humans (Edwards & Cooper 1988).

In conclusion, it appears that CE integrated into the equipment of intensive, farm-animal housing has the potential to be a suitable way of considerably increasing welfare. Before we see any large-scale, practical applications it remains to be demonstrated that CE concepts can be verified effectively without an impairment of economical returns. A further point will be to investigate whether acquired behaviour with CE equipment remains stable in animals which are subject to relocation, as this occurs frequently in farm management. Initial experimental approaches to this problem appear promising (Langbein *et al* 2006; Baymann *et al* 2007) as long as there is not too much difference between housing. Further research has to investigate the stability of the memory of the initial housing after transient relocation to other environments and the ability to transfer adequate behavioural reactions to particular CE equipment in another ambient housing environment. In order to ensure that positive affects in all phases of adaptation are exceeding non-intended negative ones, behaviour, as well as physiological reactions, must be monitored, particularly during the start of each new phase of adaptation when animals are less familiar with the challenge (Wechsler & Lea 2007).

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