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Review

Sensory stimulation as environmental enrichment for captive animals: A review

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ABSTRACT

In the wild, animals are exposed to an ever-changing array of sensory stimuli. The captive environment, by contrast, is generally much more impoverished in terms of the sensory cues it offers the animals housed within. In a bid to remedy this, and promote better welfare, researchers have started to explore the merits of sensory stimulation (i.e. stimulation designed to trigger one or more of an animal's senses) as a potential method of environmental enrichment for captive animals. This paper reviews the research in this area, focusing specifically on auditory, olfactory and visual methods of sensory stimulation. Studies exploring the efficacy of each type of stimulation as an enrichment tool are described, where appropriate, making a distinction between those that occur in the animal's natural habitat, and those that do not. Overall, it is concluded that sensory stimulation harbours enrichment potential for some animals housed in institutional settings, although the specific merits gained from these enrichments are likely to depend upon a wide variety of factors including, for example, species, sex, age and housing conditions. Programmes of sensory enrichment that target the dominant sense for the species under scrutiny, using harmless, non-stressful stimuli, are likely to result in the greatest benefits for animal welfare. Stimuli specific to a species' natural habitat should not always be considered meaningful, or advantageous, to an animal's welfare; in some cases stimuli that do not occur naturally in the wild (e.g. classical music) may offer more in the way of welfare advantages. Shortcomings in the research, and factors to consider when implementing enrichment of this nature, are discussed throughout.

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1. Introduction

Thousands of animals are housed in captive conditions worldwide, ranging from zoos and safari parks to rescue shelters and laboratories. Concern over the welfare of animals held in such settings has prompted a considerable amount of attention into ways of improving their physical and/or social surroundings. Environmental enrichment is the most common term for improvements of this nature. Although a rather vague concept, and one that is used interchangeably between different authors, environmental enrichment can be broadly defined as any technique designed to improve the biological functioning of a captive animal via modifications to its environment (Newberry, 1995).

The goals of environmental enrichment are non-specific and relatively open to debate, but it is generally agreed that enrichment strategies should encourage more in the way of species-typical patterns of behaviour, increase the ability to cope with challenges, enhance behavioural repertoire, increase positive use of the environment and/or reduce or eliminate aberrant patterns of behaviour, e.g. stereotypies (for review see Young, 2003). Over the years, studies have explored the effects of enrichments including cage size, social contacts, and the introduction of furniture, toys and other manipulanda on the welfare of a wide variety of species, with many achieving one or more of the suggested goals of environmental enrichment (for reviews see Shepherdson et al., 1998; Young, 2003; Wells, 2004; Lutz and Novak, 2005).

Lately, some attention has been directed towards exploring the impact of sensory stimulation (i.e. stimuli designed to trigger one or more of an animal's senses [e.g. vision, sight, smell]) as a method of environmental enrichment for captive animals. To date, research into the merits of such stimulation for animal well-being has been sporadic, and conclusions regarding its utility in the captive setting are still unclear. This is of some concern, in light of the fact that many animals are now routinely exposed to smells, sounds and visual images as a matter of course, in many cases without clear-cut scientific information on the advantages and/or disadvantages of such cues.

This paper reviews the research exploring the effect of sensory stimulation on the welfare of captive animals, focusing specifically on auditory, olfactory and visual methods of enrichment. Pertinent research in each area is described, and, where relevant, the need for further work is highlighted. Shortcomings in the research, and factors to consider when implementing enrichments of this nature, are discussed throughout. It is hoped that the article will shed more light on the utility of sensory stimulation as a method of environmental enrichment, allowing more informed decisions on the application of such strategies to be made by scientists, keepers and others involved in the care of captive animals.

2. Auditory stimulation

The value of music for the psychological well-being (i.e. mental health) of humans is relatively well documented. Research suggests that both our moods (e.g. Sousou, 1997; McCraty et al., 1998) and our behaviour (e.g. Ragneskog et al., 1996; Yalch and Spangenberg, 2000) can be influenced by the type of auditory stimulation we are exposed to. 'Grunge' music, a subgenre of alternative rock, for instance, can result in increased hostility, sadness, tension and fatigue, whilst 'designer music' (i.e. music created to have a specific effect on the listener) can enhance mental clarity, vigour and relaxation (McCraty et al., 1998).

Recognition of the benefits associated with music for human well-being has prompted recent research into the value of auditory stimulation as a means of enriching the environment of captive animals, ultimately with the view of meeting one or more of the suggested goals of environmental enrichment. Auditory stimulation can be loosely divided into sounds specific to a species' natural habitat, and other types of auditory signal, i.e. those not typically found in the wild.

2.1. Sounds specific to a species' natural habitat

Some of the work in this area, albeit limited in nature, has explored the welfare advantages of sounds that wild animals might be exposed to in their natural habitat. It is important to bear in mind that these are not necessarily auditory cues that animals of the same species encounter in an institutional setting, and thus cannot automatically be considered biologically relevant, or meaningful (see later).

At first glance, auditory cues of this nature seem the most sensible to employ, and indeed some studies point to their advantage. Shepherdson et al. (1989), for instance, reported more species-typical patterns of behaviour (e.g. increased brachiation [a form of locomotion in which non-human primates swing from structure to structure using their arms]), one of the suggested goals of environmental enrichment (Chamove and Anderson, 1989), in a pair of

zoo-housed Lar gibbons exposed to recorded audio-clips of their wild conspecifics. More recently, Markowitz et al. (1995) discovered that a female captive African leopard showed greater levels of activity, and decreased stereotypic behaviour, in response to the introduction of a computer-controlled device designed to play sounds of 'prey', i.e. bird noises. The fact that the device was also constructed to move and deliver food treats, however, prevents a proper analysis of the efficacy of the acoustic component of the enrichment.

Some studies have yielded relatively mixed results regarding the utility of auditory cues of this nature. Tromborg et al. (1993) found significantly higher incidences of autogrooming and vocalisation, and lower occurrences of allogrooming and scanning, in two cotton-top tamarins exposed to the recorded sounds of conspecifics and ambient environmental noise. Unfortunately, the authors of this work did not comment on the implications of their results for the animals' welfare, rendering it difficult to determine whether the changes witnessed were for the better or worse. Similarly confusing results have been reported elsewhere. For example, Ogden et al. (1994) found that two zoo-housed adult (although not infant) gorillas exposed to rain forest sounds showed an increase in locomotory behaviour suggestive of agitation. Likewise, Wells et al. (2006) found that 6 zoo-housed lowland gorillas reacted with a brief (<15 min) fear response when first presented with recorded sounds from the rainforest, running outside and having to be coaxed indoors again by staff.

2.2. Other types of auditory stimulation

Many more studies in this area have examined the influence of sounds that a species would be highly unlikely to encounter in their natural habitat on captive animal welfare. Some of this work points to welfare benefits arising from specific genres or styles of music.

Country music has featured in the literature quite heavily, with purported animal welfare advantages. Cattle, for example, have been shown to enter a milking parlour more readily when exposed to country music than 'rock 'n roll' (Wisniewski, 1977) or no auditory stimulation (Uetake et al., 1997). More recently, Houpt et al. (2000) witnessed a *non-significant* trend for a more calming behavioural influence of country music, over other genres (classical, jazz, rock) in nine ponies, as evidenced by an increased amount of time spent eating. Although not necessarily evidence of an enrichment effect, Ladd et al. (1992) reported higher incidences of head shaking and lower occurrences of preening in laying hens exposed to country music or classical/jazz, compared to a control of no auditory stimulation. The implications of these behavioural differences however, are difficult to determine in relation to animal welfare.

Classical music also appears to influence the behaviour and/or physiology of captive animals in a manner suggestive of enhanced well-being. Thus, Gvaryahu et al. (1989) reported an increase in the growth rate of chickens exposed to classical music, although concern has been expressed over the potential confounding impact of other environmental variables present in this study (Newberry, 1995). More recently, Mozart's music (sol major, K525) has been shown to increase growth and improve carcass and fatty acid composition in common carp (Papoutsoglou et al., 2007).

Behavioural measures provide further support for a potentially advantageous effect of classical music on animal welfare. A series of studies by Wells et al. (2002a, 2006, 2008) found that a commercially available CD of classical music (containing compositions by Strauss, Mozart, Bach, Grieg, etc.) exerted an enriching effect on a variety of species. In comparison to control conditions of the normal environment, the music was found to significantly increase the amount of time that kennelled domestic dogs spent resting and decrease the amount of the time spent barking (Wells et al., 2002a), reduce stereotypic behaviour (e.g. weaving, pacing) in zoo-housed Asian elephants (Wells and Irwin, 2008), and decrease conspecific-directed aggression and abnormal behaviour in zoo-housed western lowland gorillas (Wells et al., 2006). Although the authors of these studies utilised a CD designed for human entertainment, numerous CDs developed to alleviate stress in companion animals have recently appeared on the open market; virtually none of these, however, have been subject to any scientific exploration and their efficacy as a tool for enhancing welfare remains unknown.

The impact of radio broadcasts on captive animal welfare has also been subject to some examination. Radio stimulation is complex and variable, comprising a combination of acoustic elements, including the human voice, and/or different genres of music. This type of auditory stimulation, a relatively common occurrence in the captive environment, has been shown to reduce aggression, agitation and increase social affiliations in laboratory-housed chimpanzees (Howell et al., 2003), lower the heart rate (although not blood pressure or alter patterns of behaviour) of laboratory-caged baboons (Brent and Weaver, 1996), decrease abnormal behaviour in rhesus macaques (O'Neill, 1989), increase milk yield in dairy cows (Evans, 1990) and decrease aggression and improve productivity in chickens (Jones and Rayner, 1999). Guinea pigs, a relatively nervous species which is easily frightened, may gain welfare benefits from a softly playing radio designed to mask background noises (van de Weerd and Baumans, 1995), although scientific study of what effect this stimulation has on such animals' welfare is sorely lacking. Rats have not been shown to gain any welfare benefits from exposure to background radio stimulation (Pfaff and Stecker, 1976).

Whatever genre or style of music is employed in the captive setting, factors including the speed and nature of the stimulation must be taken into consideration when assessing its utility as an enrichment. Videan et al. (2007) showed that instrumental music was more effective than vocal in increasing social interactions in laboratory-housed chimpanzees; vocal music, by contrast, was more likely to decrease aggressive patterns of behaviour. The speed of the music was also found to exert a role upon the animals' behaviour, with slower tempo vocal music being more efficacious in reducing aggression in male animals than that with a faster tempo.

2.3. How does auditory stimulation exert an enriching effect?

One must question the mechanism/s by which auditory stimulation might exert an enriching effect on captive animals. On the one hand, it is possible that it simply serves as a 'mask', buffering animals from the noise of people and/or other negative acoustical stimuli, e.g. machinery, etc. If this were the case, however, one might expect an equally effective impact of all types of auditory stimulation; as evidenced, above, however, this is not always the case. The possibility that there is something specific and enriching about certain types of auditory stimulation must also be acknowledged. For instance, whilst still not conclusive, there is some evidence that Mozart's Sonata K. 448 may promote cognitive functioning (e.g. spatial temporal reasoning) in animals and humans (e.g. Rauscher et al., 1993; Hetland, 2000; Gilleta et al., 2003). Other mechanisms may be at play. Chikahisa et al. (2007), for example, found that ovarian steroids, and in particular progesterone, may be involved in the anxiolytic effects of music in female mice.

Further work is needed to unravel the specific acoustic elements that animals respond to, and determine whether they serve as a mask to extraneous noise or exert an enriching neurophysiological effect in their own right, whether directly or indirectly.

2.4. A note of caution

The studies reported above paint a somewhat confusing picture in regards to the implications of auditory stimulation for captive animal welfare. Taken together, there is relatively little evidence to suggest that sounds from an animal's natural environment are enriching, and highlight that what may be considered 'natural' may not necessarily be meaningful to the animals concerned, or particularly beneficial for their well-being (e.g. Ogden et al., 1994; Wells et al., 2006). Indeed, this type of stimulation may even be counter-productive to improving welfare in some animals (e.g. by increasing stress), particularly those born in captivity and having never encountered sounds from the wild. In the days of naturalistic zoo exhibits, this may be a factor that needs consideration. Further work in this area, ideally using larger numbers of subjects from different institutional settings, is clearly required before firm conclusions on the utility of sounds from the wild for captive animals can be established. Music, by contrast, particularly that of the classical or country variety, seems to hold some potential as an enrichment tool, although, again, further work, using a wider variety of acoustic stimuli, larger groups of animals, and more standardised measures of animal well-being, is needed before generalisations can be made.

Although certain auditory stimuli might hold enrichment potential for some animals, what may be more important for captive animal welfare than the *introduction* of additional acoustic stimulation, is the overall *reduction* of ambient noise. The captive environment can be an unpleasantly noisy one, with loud noises having been shown to result in reduced reproductive and cardiovascular function, increments in cortisol levels, disturbed sleep-wake cycles, seizures and/or a limited ability to communicate with conspecifics (e.g. Sales et al., 1999; Baldwin et al., 2007; Turner et al., 2007). Damage to the auditory system as a direct result of exposure to high levels of sound has also been noted in some laboratory-housed species (Peterson, 1980). Although specific types of auditory stimuli might be considered enriching, there is the potential for this extra noise to do more harm than good. McDermott and Hauser (2007) found that whilst laboratory-housed cotton-top tamarins and common marmosets exhibited a preference for music of a slow, over a fast, tempo, when presented with a choice between slow tempo music and silence, the animals preferred silence. Attempts should be made to reduce overall sound levels in captive settings. If additional auditory stimuli are added as an enrichment, then the ability for the animals to exert control over the sound (i.e. turn it on and off) should be considered (see Novak and Drewson, 1989).

Although, arguably, a less important factor than animal welfare, many institutions need to consider the impact of the auditory environment on the human audience, e.g. visitors, staff. What is best for the animals, may not necessarily be best for the people, and striking a balance between these two user groups can sometimes present a challenge. Wells et al. (2006), for instance, reported a mismatch between the type of auditory cue most appropriate for lowland gorillas' welfare (classical music) and that preferred by zoo visitors (sounds of the rainforest). Environmental features can have a striking effect upon people's perceptions of the animals housed within. Thus, Wells et al.'s (2006) study showed that visitors considered the gorillas to look less aggressive and more 'natural' during exposure to recorded sounds from the rainforest. Earlier work has shown that the visual environment of rescue shelters can have an impact upon visitors' perceptions, and the subsequent adoption rates, of kennelled dogs (Wells and Hepper, 1992); although it has not been subject to scientific investigation, it is possible that the auditory environment plays an equally important role in shaping perceptions of animal desirability; further work is needed to explore this idea.

3. Olfactory stimulation

Many species are driven by their sense of smell, with animals utilising olfactory signals to communicate with intra- and inter-specifics, locate prey, attract mates and/or find food (see Hurst et al., 2008). Despite the importance of odour cues for animals in the wild, the use of disinfectants and other sanitising stimuli can render the captive environment scant on meaningful olfactory information (Clark and King, 2008). In light of this, attempts have recently been made to meet the suggested goals of environmental enrichment through the addition of odours, whether in the form of olfactory stimuli that are specific or non-specific to an animal's natural habitat, or pheromonal in nature.

3.1. Odours specific to a species' natural habitat

Many odours introduced to the captive environment of animals could be considered biological in nature, typically

comprising body odour/s (e.g. fur), urine and/or faecal material from prey or predators found in the animals' natural habitat.

The introduction of olfactory stimuli from natural prey has been shown to have largely enriching effects, in many cases facilitating some of the suggested goals of environmental enrichment, e.g. increases in behavioural diversity (Chamove and Anderson, 1989). For example, increased activity and social affiliations have been observed repeatedly in zoo-housed lions exposed to the scents of deer hunting lure and dung from prey species including zebra, gazelle, antelope and kudu (Powell, 1995; Baker et al., 1997; Schuett and Frase, 2001).

The welfare advantages of introducing olfactory stimuli from natural predators are less clear, and indeed many studies suggest a potentially detrimental effect. Exposure to cat urine, for example, has been found to increase intragroup aggression in male mice (Zhang et al., 2008), and cotton-top tamarins have been shown to exhibit high anxiety responses to the faecal odour of potential predators (margay, tayra); non-predatory faecal exposure (capybara, paca), by contrast, yielded low anxiety responses in the same animals (Buchanan-Smith et al., 1993). Sheep and cattle have also been shown to exhibit behavioural changes suggestive of anxiety (Terlouw et al., 1998), including reduced feeding (Pfister et al., 1990; Arnould and Signoret, 1993; Arnould et al., 1993), when exposed to the faeces of domestic dogs. More recently, tapirs have been shown to display 'stress' and 'jumpiness' in response to exposure to jaguar urine (Calderisi, 1997).

Not all studies point to a detrimental effect of predatory odours on captive animals. For example, Christensen and Rundgren (2008) found that horses were not frightened *per se* by the scent of wolf odour, as evidenced by only minor behavioural reactions (e.g. an increased number of eating bouts) and no increase in heart rate, following exposure to the olfactory stimulus. That said, the animals did exhibit a higher level of vigilance (e.g. increased sniffing), upon detection of this odourant. Boon (2003) found no difference in the behavioural reaction of two female captive-born, zoo-housed Goldei's monkeys to predatory (cheetah and ocelot faeces) and non-predatory (peppermint oil) scents. One might have expected the animals in these two studies to have shown fear reactions to the predatory odours, in light of the belief that the olfactory recognition of predators may be innate (Buchanan-Smith et al., 1993). These experiments raise the question of whether odours that an animal has never been exposed to in the past, even if considered to be inherently relevant, are really meaningful to all species, or individuals.

3.2. Other types of olfactory stimulation

Essential oils and other aromatic compounds from plants have been used for decades in the treatment of human ailments, with effects dependent upon the type of stimulus employed. Thus, lavender, chamomile and sandalwood have been shown to reduce anxiety and encourage positive affect (e.g. Schwartz et al., 1986; Roberts and Williams, 1992; Moss et al., 2003), whilst peppermint, jasmine and rosemary have been reported to improve alertness and enhance cognitive performance, e.g. increase the speed of mental arithmetic challenges, enhance vigilance and speed of reaction on computer-based tasks (e.g. Kovar et al., 1987; Diego et al., 1998; Warm and Dember, 1990).

Although biologically meaningless to many animals, recent work has shown that essential oils and other plant-derived odourants might be able to improve the welfare of certain species. As in humans, some of these odours appear to encourage relaxation and alleviate stress. The ambient odour of lavender, for instance, has repeatedly been shown to decrease motility in laboratory-housed rodents (Buchbauer et al., 1991; Lim et al., 2005; Shaw et al., 2007). The same herb has been shown to reduce activity and vocalisations in dogs housed in rescue shelters (Graham et al., 2005a), behavioural changes suggestive of increased relaxation. Interestingly, sheltered cats have not been found to gain any welfare benefits following exposure to the same stimulus (Ellis, 2007), although the different modes of odour presentation in the two studies (diffused into the air for dogs; impregnated onto cloths for cats), may explain, in part, the discrepancy in results obtained.

Lavender may not only be of use in the housing of animals, but may also offer welfare advantages for individuals in transit. Bradshaw et al. (1998) found that both the incidence and severity of the physical symptoms associated with travel sickness in pigs (i.e. foaming, retching, vomiting) could be reduced significantly by the provision of lavender-scented straw. More recently, Wells (2006) found that behavioural symptoms of over-excitement in dogs travelling in their owners' cars could be alleviated through the addition of lavender-impregnated cloths, resulting in a lower occurrence of barking and hyperactivity.

Some odours appear to have a more stimulating effect on animals. The essential oils of peppermint and/or rosemary (which belong to the same botanical family as catnip) have been found to increase the activity level of captive mice (Kovar et al., 1987; Umezu et al., 2001), lions (Powell, 1995; Pearson, 2002), chimpanzees (Struthers and Campbell, 1996), and, more recently, dogs (Graham et al., 2005a). Animals that have been housed in captivity for lengthy periods of time can develop behaviours symptomatic of learned helplessness, e.g. increased resting/sleeping (Wells et al., 2002b). The introduction of odours with stimulating properties may be advantageous for such animals, helping to promote mental stimulation and psychological well-being. There is always the possibility, however, that animals exhibiting a depressive-like state, may go on to develop a more active type of aberrant behaviour (e.g. stereotypy) following exposure to stimulating odours. Adding odours that cause increased agitation or stress may actually do more harm than good, and further work is needed to explore the impact of these stimuli in more depth before firm conclusions on their welfare implications can be drawn.

Other odours besides those mentioned above may also hold some enrichment potential for captive animals, whether as sedatives or stimulants. Studies on mice and rats have shown anxiolytic effects of inhaled valerian (Komori et al., 2006), cedarwood (Kagawa et al., 2003),

lemon oil (Komiya et al., 2006) and chamomile (Yamada et al., 1996), whilst captive felids have been shown to gain arousing benefits from the introduction of spices such as chilli, cinnamon, cumin, nutmeg and ginger (Schuett and Frase, 2001; Pearson, 2002; Wells and Egli, 2004; Skiebiel et al., 2007). Herbs including catnip, lemongrass, allspice and ylang ylang have also been found to exert an excitatory effect on captive lions (Pearson, 2002), black-footed (Wells and Egli, 2004), and domestic (Ellis, 2007), cats.

3.3. Pheromone stimulation

Lately, some attention has been directed towards the use of pheromones as a method of enrichment for captive animals. Spielman (2000), for example, found that Feliway (*Ceva Sante Animale*, France), a synthetic analogue of domestic cat facial pheromone, resulted in augmented levels of spraying and head rubbing (suggestive of increased behavioural repertoire) in zoo-housed tigers, although it had no marked effect on lions.

The canine equivalent of this product (Dog Appeasing Pheromone, DAP, *Ceva Sante Animale*, France), which has been shown to be effective in curtailing some problem behaviours (e.g. firework phobia, travel-related problems) in pet dogs (e.g. Sheppard and Mills, 2003; Estelles and Mills, 2006), also has potential as a method of enrichment for captive animals. Thus, Tod et al. (2005) found a significantly reduced frequency of barking in sheltered dogs subjected to DAP exposure for 7 days, although maximum barking amplitude was not significantly altered.

Livestock, and in particular, pigs have also been shown to gain benefits from 'pheromonatherapy'. Aggressive behaviour during the regrouping of such animals, for instance, has been shown to be reduced by exposure to sexual pheromones (McGlone et al., 1987; Petherick and Blackshaw, 1987). Nursing behaviour has also been shown to be regulated by maternal pheromones in pigs. Morrow-Tesch and McGlone (1990a, 1990b) found that piglets would not nurse when odours thought to contain maternal pheromones were removed from the skin of their lactating mothers. In a similar vein, piglets have been shown to engage in less aggressive behaviour and gain more weight during post-weaning mixing when exposed to synthetic compounds containing elements of a maternal pheromone (Pageat and Tessier, 1998; McGlone and Anderson, 2008). Very recently, pigs subject to the vibrations of a transport simulation, a known stressor, showed significantly greater heart rate decrements in response to the scent of a synthetic compound containing maternal pheromones, compared to the conditions of a non-odour control or a non-relevant unfamiliar odour, i.e. hartshorn oil (Driessen et al., 2008).

Horses have been subjected to little attention with regards the value of pheromonal therapy, but the small amount of research conducted in this area points to potentially beneficial effects. Falewee et al. (2006) found that 40 saddled horses exposed to a fear-eliciting situation (walking through a fringed curtain to enter a stable), showed fewer behavioural signs of anxiety following two nasal sprays of a synthetic Equine Appeasing Pheromone (EAP), than animals who performed the same task minus this pheromonal exposure. The slight time lag (~20 min) between application of the pheromonal treatment and observable effects on behaviour, however, suggests that EAP may be of optimum benefit in foreseeable fear-eliciting situations.

3.4. A note of caution

The above studies highlight the potential for certain odours to be used as enrichment for captive housed animals. The success of olfactory stimulation as a method of environmental enrichment, however, may depend, to some degree, upon the species under scrutiny. Non-human primates, who rely more heavily upon their sense of sight, seem to gain fewer welfare advantages than more olfactory-driven species. Thus, Ostrower and Brent (2000) found that the application of 'pleasant' (e.g. vanilla, orange, peach) and 'unpleasant' (e.g. moth balls, cigar smoke, limburger cheese) odours to fleece cloths elicited no more attention from 5 groups of 21 captive chimpanzees than cloths devoid of olfactory stimuli. Wells et al. (2007) similarly found that olfactory stimulation in the form of odour-impregnated (*orange, almond, vanilla, peppermint*) cloths had no significant effect on the behaviour of 6 zoo-housed gorillas. Taken together, these studies suggest that odour cues may not be overly salient to such animals, at least in captivity. Whilst olfactory stimulation should not be completely overlooked as a method of enhancing the environment of captive non-human primates, enrichment strategies that facilitate vision-driven goals (e.g. foraging, manipulable objects) may be more appropriate for such animals (see later).

Some caution needs to be exerted with regards the health and safely implications of certain odours. As highlighted above, some of the odours considered biologically 'relevant', particularly those from potential predatory species, may induce stress and should be used sparingly in the captive environment, if at all. Many of the other studies carried out in this area have utilised essential oils, which come with their own concerns. For example, whilst moderate doses of lavender can have an anxiolytic effect, higher doses can cause sedation (Shaw et al., 2007), a potentially undesirable outcome in the captive environment. The issue of toxicity also needs to be addressed in relation to the use of essential oils and plant derivatives. Some authors have reported unwanted physical side effects (e.g. vomiting, skin irritation) in pet cats exposed to potpourri (Richardson, 1999; Foss, 2002), and deaths arising from nightshade plants have been reported in some non-human primates (Engel, 2002). Since lavender, and certain other essential oils, are not normally recommended for use in pregnant woman, there may also be issues over the use of these stimuli in certain cohorts of animals.

Although this review has focused on the value of odour *introduction* for captive animal welfare, the avoidance of natural odour *removal* also needs to be mentioned. Routine husbandry practices can remove important olfactory information, both regarding the self and others in the group. Many species (e.g. non-human primates, felids) scent mark in a bid to demarcate territories, advertise reproductive state, signal resource ownership and convey

information on social status (e.g. Drea and Scordata (2008)). The natural scents left behind through elimination (both urination and defecation), hair and sweat glands can also provide cues that are both informative, and potentially enriching, in their own right. As a potential solution to the problem of odour removal, Clark and King (2008) recommend cleaning half of an animal's enclosure at a time, thus allowing the retention of some meaningful odour cues.

4. Visual stimulation

Visual stimulation has long been used in animal behaviour research. A wide selection of stationary photographs and dynamic video films have been utilised over the years to test animals' abilities on abstract tasks, as a replacement for mirrors in the study of 'self-awareness' and as alternatives for real stimuli, e.g. other animals (for review see D'Eath, 1998). More recently, attention has been directed towards the utility of visual stimulation as a method of enrichment for animals housed in captivity.

4.1. Television and videos

Much of the work in this area has explored the value of moving televised video images as a form of enrichment for captive animals. Positive behavioural changes suggestive of an enrichment effect arising from this type of visual stimulation have been reported in a wide variety of species. These include a reduction in stereotypic behaviour and the exhibition of more socially appropriate responses in non-human primates (e.g. Plimpton et al., 1981; Capitanio et al., 1985; Brent et al., 1989; Meunier et al., 1989; Platt and Novak, 1997), increments in socially facilitated feeding (Keeling and Hurnik, 1993), and reduction in fear of an unfamiliar environment (Clarke and Jones, 2000), in chickens, and a lower incidence of vocalisation in kennelled dogs (Graham et al., 2005b).

One might expect moving images of biologically meaningful stimuli to attract more attention, and/or exert a more enriching effect, than those of less biological value. The results from work in this area, however, are conflicting. Chimpanzees have been found to be no more likely to watch moving images of conspecifics or humans than those that are less biologically relevant (Bloomsmith et al., 1990; Bloomsmith and Lambeth, 2000). By contrast, domestic dogs have been reported to spend slightly, although not significantly, more time looking at television programmes of conspecifics and humans, than more 'meaningless' images of other species, e.g. penguins, polar bears. Ellis and Wells (2008) similarly found that domestic cats exposed to moving images high in potential prey material (rodents, fish, birds) spent more time looking at the television monitors than animals presented with images of biological relevance.

What might be more important than the actual content of the video material is the rate of change of the stimuli presented, i.e. novelty. Work on non-human primates has shown that continuously changing stimuli maintain an animal's attention for longer (Butler, 1961; Platt and Novak, 1997). Jones et al. (1996) likewise found that chicks may be more intrinsically attracted to complex unfamiliar video images than those that are familiar, again highlighting the important role that novelty may play. More recently, Ellis and Wells (2008) found that televised moving images of a snooker game, with its regular camera angle changes and quick linear ball movements, attracted the attention of sheltered cats better than the presence of a blank television screen.

4.2. Computer games

Another form of visual stimulation that has attracted some attention is that of computer-assisted enrichment, i.e. stimulation in the form of computer-based challenges. Some of this work has been conducted specifically to assess cognitive functioning and abilities, e.g. learning, memory span (Rumbaugh et al., 1989; Andrews and Rosenblum, 1993, 1994). However, of late, the value of computer-based challenges as a method of environmental enrichment has been explored. Much of this work has been conducted on non-human primates, although it has yielded conflicting results. Platt and Novak (1997), for instance, allowed rhesus macaques to play a video game requiring manipulation of a joystick that moved a cursor along a computer screen in order to receive a food treat. The authors reported increments in activity levels and a lower degree of passive social contact between animals as a result of the visual stimulation, leading them to conclude that video games may be a successful form of enrichment for such animals. More recently, Tarou et al. (2004) found that a computer-joystick system designed to increase in complexity with learning was readily employed by zoo-housed orangutans. Unfortunately, the device encouraged higher levels of aggression and anxiety-related behaviours (scratching, yawning), rendering its utility as a method of enrichment questionable, particularly for group-housed animals. That said, chimpanzees (Bloomsmith and Lambeth, 2000), rhesus monkeys (Platt and Novak, 1997) and pigtail macaques (Lincoln et al., 1994) have not been observed to fight over access to a computer-based task, suggesting that there may be species (or other) differences at play.

4.3. Mirrors

Mirrors, and other reflective devices, have been used for many years as a tool for testing self-recognition/awareness in non-human species, e.g. primates (e.g. Gallup, 1970) dolphins (Reiss and Marino, 2001), elephants (Plotnik et al., 2006). Research is now pointing towards the potential value of this type of visual stimulation as a method of enrichment for captive animals, particularly individuals subject to social isolation. Mirrors have been shown to reduce short-term stereotypic weaving in stabled horses (McAfee et al., 2002; Mills and Davenport, 2002), reduce the heart rate of visually isolated heifers (Piller et al., 1999), lower endocrine and physiological reactions to partial isolation in sheep (Parrott et al., 1988), increase behavioural complexity in caged rabbits (Jones and Phillips, 2005) and provide a source of stimulation to laboratory-housed non-human primates (e.g. Gallup and Suarez, 1991; Lambeth and Bloomsmith, 1992; Brent and Stone, 1996).

Not all animals gain enrichment benefits from mirrors, however. This type of stimulation has been shown to be slightly aversive to laboratory-housed mice, resulting in reduced feeding in the presence of mirrors and avoidance of a cage containing mirrors in a preference test challenge (Sherwin, 2004). Rabbits have also been reported to find the initial presence of a mirror 'disturbing', as evidenced by an increase in vigilance behaviour, i.e. time spent looking alert (Jones and Phillips, 2005).

4.4. Colour

Colour is believed to have a significant effect upon many human facets. Over the years, colour has been shown to affect our moods, physiological reactions, cognitive functioning and emotional well-being (for review see Wells et al., 2008). For this reason, so called 'colour therapy' is now commonly employed as a form of treatment for those with depression and anxiety-related ailments (e.g. Torrice, 1990).

Colour may also have an effect upon the psychological well-being of animals, and may play an important role in enrichment strategies for those housed in captive settings. Certain colours may be relatively aversive to some species. Many birds, for example, avoid red coloured foods and other objects (e.g. pigeons, Sahgal et al., 1975), and red coloured environments have been shown to be aversive to monkeys (Humphrey, 1971; Humphrey and Keeble, 1975), domestic chickens (Prayitno et al., 1997) and mice (Sherwin and Glen, 2003). Whilst the colour red may be less than enriching for some animals, the 'cooler' colours of the spectrum may offer some welfare benefits. A preference for the colour blue, for example, has been shown in moths (Kelber, 1997), bumblebees (Keasar et al., 1997), robins (Murray et al., 1993) and bobwhites (Mastrota and Mench, 1995). Zoo-housed chimpanzees and gorillas have recently been shown to prefer blue and green coloured stimuli to the same objects coloured red (Wells et al., 2008), and anxiety-related pacing has been found to be mitigated by green lighting in zoo-housed chimpanzees (Fritz et al., 1995).

4.5. A note of caution

In relation to auditory and olfactory stimulation, visual enrichment probably comes with a weaker cautionary note. In many cases, animals can simply choose to avoid visual stimuli that they find aversive, unlike auditory and olfactory stimuli, which tend to be more encompassing and may be more difficult to exert control over. Moreover, many authors have reported long-term (i.e. over several weeks) use of visual enrichment devices in non-human primates, suggesting such animals have a keen interest in this type of stimulation (e.g. Lincoln et al., 1994; Platt and Novak, 1997). This means, care still needs to be taken in regard to the nature of visual stimuli presented to animals. Most types of visual presentation (e.g. televised images) do not allow for any physical contact with the stimulating items, e.g. moving images of prey. This may have the potential to lead to frustration. For example, whilst laser pointers were initially considered to be a suitable method of enrichment for cats (e.g. Holmes, 1993; Landsberg, 1996), recent concerns over their use have been raised, believing that the cats' inability to capture the light may give rise to frustration and obsessive compulsive behaviour (see Ellis and Wells, 2008). Further research is needed to ensure similar effects are not evident with the long-term use of televisions in the captive environment.

The visual systems of the species in question must also be considered carefully. Non-human primates are well renowned for their well-developed sense of sight, perceiving images in much the same way as people (e.g. Napier and Napier, 1986); these animals are therefore likely to see the visual stimuli presented to them in much the same way as ourselves. Other animals, however, may perceive things very differently. Dogs, for example, have a flicker fusion frequency of between 70–80 Hz (compared to 50–60 Hz in humans, Hart, 1992); thus television programmes, which have a refresh rate of about 60 Hz, are believed to appear as rapid flickering to such animals (Coile et al., 1989). Although, Graham et al. (2005b) found that many of the dogs in their study 'watched' the television programmes presented to them, the two-dimensionality of this type of stimulation may present problems for some individuals. The use of colour as a method of enrichment raises similar issues, particularly for those species that do not possess trichromatic colour vision, e.g. dogs, cats.

5. Conclusion

Taken together, the literature reviewed above suggests that sensory stimulation in the form of auditory, olfactory and visual cues, holds some potential as a method of environmental enrichment for captive animals. Many of the studies undertaken have shown sensory stimulation to result in changes in the biological functioning of animals in a manner suggestive of enhanced physical and/or psychological welfare, and in this respect sensory stimulation could be considered to meet many of the suggested goals of environmental enrichment (see Young, 2003).

It is difficult to ascertain exactly what types of sensory stimulation are the most appropriate to employ in any given situation. The merits gained from each approach are likely to depend quite heavily upon a number of factors, including, for example, species, sex, age, housing conditions, etc. The role of individual differences (e.g. personality, origins) is equally important; what may be enriching for one animal in a group, may well be aversive to another. It must be borne in mind that each type of sensory stimulation comes with its own unique set of potential problems, and in all cases consideration needs to be made to ensure that the addition of sensory information does not do more harm than good. As with the introduction of any enrichment programme, a careful cost-benefit analysis, weighing up the advantages and disadvantages of the enrichment, should be made before any scheme is put into practice. Importantly, enrichment strategies should be adopted that ultimately aim to improve the biological functioning of the species under scrutiny. Some of the least successful studies have utilised stimuli that, arguably, could be considered biologically meaningless to the animals concerned (e.g. olfactory stimulation for non-

human primates). Programmes of sensory enrichment that target the dominant sense, using harmless, non-stressful, stimuli, are likely to result in the greatest benefits to animal welfare. Stimuli specific to a species' natural habitat should not necessarily be considered meaningful, or advantageous, to the animal under scrutiny, and in many cases stimuli that do not occur naturally in the wild may offer more in the way welfare advantages.

Further research in this area is very much needed. Many of the studies carried out have utilised small groups of animals (<5) housed in single institutional settings, and findings are therefore hard to generalise. Relatively few studies, particularly those concerned with auditory and olfactory stimulation, have explored the long-term impact of such enrichments (i.e. beyond several days), and it is unclear whether animals exposed to these stimuli gain anything more than short-term welfare benefits.

Many institutions housing animals are now paying more attention to the animals' environment and the important relationship between housing and well-being. This review demonstrates that sensory stimulation can be utilised successfully as an enrichment for captive animals, although the methodological weaknesses (e.g. low sample size) that typically plague research of this nature, render firm conclusions difficult to draw. Further research in this area will hopefully ensure that developments continue to be made in our understanding of how to ideally house animals in order to promote both their physical and psychological well-being.

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