# Environmental Enrichment as a Strategy for Mitigating Stereotypies in Zoo Animals: A Literature Review and Meta-analysis

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# 9 Environmental Enrichment as a Strategy for Mitigating Stereotypies in Zoo Animals: a Literature Review and Meta-analysis

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### Editorial Introduction

Zoo animals provided some of the earliest and best described cases of stereotypic behaviour, with examples including the repetitive pacing of large carnivores (see Chapter 2) or the monotonous swaying of elephants. Because stereotypic behaviour often dismays the public, as well as causing concern about welfare and stress, zoos have taken the lead in finding practical ways to reduce it. Usually these attempts are through what is known as 'environmental enrichment' – typically alterations to the enclosure, or additions of particular objects or stimuli, made with the broad aim of increasing welfare. In this chapter, Swaisgood and Shepherdson present an overview of the likely causes of stereotypy in zoo animals, bringing together many of the ideas of the previous chapters: the frustration of specific motivated behaviours; a general lack of physical complexity and/or sensory stimulation; and stress (though, rightly or wrongly, they downplay the role of major CNS changes in zoo animals). They show how in practice this has correspondingly led to enrichments designed to offer specific behavioural opportunities (often foraging-related), or to make enclosures more naturalistic, complex or stimulating (although relatively few to date have aimed to reduce stress *per se*). But how well does such enrichment work? After all, truly recreating natural environments, or offering genuine opportunities to, say, hunt, will often be hard if not impossible, and furthermore, the real psychological needs of most exotic species are as yet unknown.

Happily, studies of enrichment and its effects on stereotyping zoo animals have accumulated to the point where they are ripe for meta-analysis, which the authors of this chapter have done to great effect. They pool and analyse around 20 papers, dealing with about 100 individuals across multiple taxa. Their findings include that those animals with the most time-consuming stereotypies attract the most complex, multi-component 'everything-but-the-kitchen-sink' forms of enrichment. While this makes it hard to assess exactly what aspects of it 'work', this is an appropriate practical response and also seems effective, with the behaviour of these highly stereotypic animals being just as successfully reduced as is that of much less stereotypic individuals. Indeed overall, Swaisgood and Shepherdson find an impressive degree of success, enrichments typically reducing stereotypy-performance by half. It is notable, however, that not a single case eliminated the behaviour altogether, making it even more pressing to ascertain what 'works' and what does not. Are some types of environmental enrichment better than others, for example? Surprisingly, not obviously so, though the authors highlight multiple possible reasons for this. Enrichments that are implemented for a long time, however, do seem more effective than more short-lived forms. Boxes in this chapter, further discuss the role of enrichment in the captive breeding of pandas; the practical realities of implementing enrichment programmes in zoos; the effects of enrichment on laboratory primates; and alarmingly, how the relative effectiveness of different enrichments can depend on precisely how their influence on stereotypy is measured.

The authors end with a very thoughtful guide to future work. Research in zoos is typically hampered by the small number of animals available, and also by the difficulty of providing sufficient scientific control in an environment where the primary goal, rightly, is to eliminate rather than merely understand stereotypies. The chapter therefore ends with suggestions as to how research on stereotypies in zoo animals could be improved – a topic potentially of great fundamental as well as practical value.

***JR & GM***

## 9.1. Introduction

The focus of this chapter is on lessons learned from studies of enrichment and stereotypy in the zoo community. Zoos have a rich history of pioneering work in this area, yet modern zoo research has not kept pace – and perhaps cannot keep pace – with research on lab and farm species. We in the zoo community have access to a diversity of species, making for interesting comparative studies, but our studies are often compromised by issues of limited sample sizes and little experimental control. Zoo enrichment practitioners also face great challenges in understanding the welfare of such a diverse array of wild animals. However, a renewed effort in this arena will pay off considerably, for no other community has so much unrealized potential.

Most modern zoos aim to present animals to their visitors in a way that conveys information about natural history and fosters positive attitudes to animals and their natural environments. Today the emphasis is on using this connection to encourage visitors to make 'environmentally friendly' choices that will benefit wildlife in the future. Zoos can also take part directly in the conservation of wildlife by augmenting and re-establishing wild populations with individuals reared or bred in zoos (e.g. utchins and Conway, 1995). Thus, zoos need to maintain a wide diversity of species with an emphasis on genetically sustainable, phenotypically normal populations of rare and endangered species (e.g. see Box 9.1). Given this background, many zoos are highly motivated to tackle stereotypies when they occur in their animal collections for several key reasons.

First, concern for animal well-being is a fundamental ethic of modern zoos, and stereotypic behaviour is an indicator of potential welfare problems. Second, stereotypies may indicate stress, and the deleterious effects of stress on reproduction and health have been widely documented (e.g. Moberg, 2000; Shepherdson *et al.*, 2004). Successful reproduction is central to the ability of zoos to display and reintroduce endangered species.

**Box 9.1.** Enrichment and Captive Breeding Programmes for Endangered Species: the Case of the Giant Panda

**R. Swaisgood**

In today's zoo, and the conservation community at large, a prominent goal of maintaining wild animals in captivity is to support efforts to conserve endangered species. The purpose of these captive breeding programmes is to create a genetic reservoir as an insurance policy should the species become extinct or genetically compromised in the wild. Because poor animal well-being can be a significant obstacle to reproduction, much effort is made to monitor signs of poor adjustment to captive conditions, including assessment of stress and abnormal behaviour, and to determine what environmental provisions are necessary to sustain the species physically and psychologically (Shepherdson, 1994; Swaisgood, 2004b). The highly endangered giant panda makes a good case study illustrating just how integral such efforts are for successful captive breeding. Notorious for their reluctance to breed in captivity, earlier efforts focused on the role of olfactory communication in promoting libido (Swaisgood *et al.*, 2000). However, it soon became apparent that communication alone would not solve all breeding problems. Many pandas suffered from relatively severe stereotypies, which appeared linked to reproductive problems. Assuming that behavioural needs were therefore not being met, researchers set out to devise an enrichment programme with the short-term goal of reducing stereotypies and the long-term goal of increasing reproduction (Swaisgood *et al.*, 2005a,b). Q1 Initial tests showed that simple novel objects commanded the attention of pandas living in impoverished conditions, performing equally well compared with enrichments devised to create opportunities to work for food. These enrichments led to a significant reduction in stereotypies and signs of feeding anticipation and promoted behavioural diversity (Swaisgood *et al.*, 2001). These tests also shed light on the motivation underlying stereotypy performance. The novel objects served no biological goal other than the opportunity to *perform* behaviours and/or gather information, yet the effects of this enrichment continued into the aftermath of the enrichment interaction, suggesting that motivation to perform stereotypies was influenced, i.e. effects were not just the result of taking up time to perform stereotypies. From these initial insights researchers continued to expand the enrichment programme, often adapting it to the needs of individual animals that still failed to reproduce (Zhang *et al.*, 2004). Eventually, the programme included enclosure redesign, dietary change (particularly increased bamboo feeding) and other changes in basic husbandry practices. All this to much effect, for this breeding centre in China grew from about 25 to nearly 80 animals in the space of a few years post-implementation of this holistic programme (Swaisgood *et al.*, 2005a,b).

Third, the educational role of zoos can be compromised by animals displaying stereotypies: stereotypic behaviour is not a good representation of 'natural' behaviour, and is frequently perceived negatively by zoo visitors. Finally, abnormal behaviours may reduce the chances of an animal surviving in the wild, or indicate other problems that may negatively impact an animal's chance of surviving in the wild after release (Shepherdson, 1994; Vickery and Mason, 2003). Since stereotypies are rarely if ever seen in the wild, the key to resolving them clearly must reside in making appropriate changes to the zoo environment. These kinds of changes are usually encompassed by a general philosophy of animal husbandry termed 'environmental enrichment'; a term now almost synonymous with efforts to improve animal well-being in the zoo community. The purpose of this chapter is to review the effectiveness of environmental enrichment in reducing stereotypic behaviour in zoo animals. In Sections 9.2 and 9.3, we discuss enrichments and how they might tackle stereotypies, before analysing their success in practice in Section 9.4. Q2

## 9.2. What is Environmental Enrichment?

Environmental enrichment is a loosely defined term that describes actions taken to enhance the well-being of captive animals by identifying and providing key environmental stimuli (Shepherdson, 1998). Its conceptual roots can be traced back at least to the beginning of the last century, when primatologist Yerkes (1925) emphasized that captive animals should be given opportunities for both play and 'work' activities comparable to those performed by wild animals. The concepts subsequently grew in sophistication with the work of zoo biologists like Heini Hediger, Desmond Morris, Hal Markowitz and many others working in related fields. Their important contributions have been described elsewhere in greater detail (see Shepherdson, 1998).

Environmental enrichment aims to both pre-empt and to cure stereotypies and other welfare problems. In practice, however, it is often reactive, and targeted at individuals or groups with overt behavioural problems. Examples range from naturalistic foraging tasks to objects introduced for manipulation, play and exploration, novelty and sensory stimulation. Social stimulation, and even training by humans (e.g. Kastelein and Wiepkema, 1988), are often described as enrichment. Renovating old and 'sterile' exhibits and the construction of new exhibits, with the design goal of providing enhanced opportunities for the expression of natural behaviour patterns, are also forms of enrichment (e.g. Little and Sommer, 2002). The activities performed in zoos in the name of environmental enrichment thus cover a multitude of innovative, imaginative and ingenious techniques, devices and practices, and the processes of developing and monitoring these enrichments are ever being improved (see Box 9.2).

**Box 9.2.** Enriching with SPIDER

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Environmental enrichment in zoos and aquaria has historically been a fairly unstructured, grassroots movement, with news of apparent successes spread by word-of-mouth, presentations at zoo-oriented conferences, newsletters like *Shape of Enrichment* (www.enrichment.org), and other web-based means (e.g. www.enrichmentonline.org). Enrichment goals were often rather unclear; 'success' poorly defined; enrichment choices somewhat arbitrary (often based on precedent rather than specific end results) and evaluation very subjective, with little done to report successes or failures consistently. Recent years, however, have seen a growing call for a more formal, goal-oriented approach (e.g. Mellen *et al.*, 1998; Mellen and MacPhee, 2001; Shepherdson, 2002). Indeed, in North America, legislation from the U.S. Department of Agriculture in 1991 required facilities with non-human primates to develop formal enrichment plans, and this prompted the American Zoo and Aquarium Association (AZA) to extend this requirement to all animals in AZA-accredited collections. Using guidelines like the 'SPIDER' model, the AZA proposes that this process involve: Setting goals; Planning; Implementing; Documenting; Evaluating and Readjusting (e.g. www.animalenrichment.org).

**(S)** *Setting goals* ideally involves knowing which behaviours are important for an animal's health and psychological well-being. Without data on what captive wild animals really need, this typically comes from understanding the animals' natural history, 'gut feelings' and general observations. Goals might be to provide opportunities to perform natural behaviour patterns (e.g. providing polar bears with hay to make day-nests, analogous to the tundra beds used by some bears in the wild); and/or to increase cognitive stimulation (perhaps via 'non-natural approaches' like computer terminals, or the human-animal communication involved in training) and/or to reduce stereotypy.

**(P)** Enrichment suitability needs careful consideration by keepers, curators, veterinarians and nutritionists during *planning*. The impact that enrichment may have on animal welfare is considered, but also safety, cost, space availability and visitor reactions – since these influence what is practical. Many exhibits were not initially designed to maximize animal welfare by current standards, and so during planning/approval there can be conflict between what is in the best interest of the animals, and the constraints of what is possible (e.g. not having space to house a whole pride of lions) or suitable (e.g. not wanting to feed carnivores whole carcasses in front of visitors).

**(I)** *Implementation* is the next step. Many factors impact the effectiveness of enrichment, including where and when the enrichment is provided, how long it is given, and to which animals (factors which remain relatively understudied). To be effective, enrichment needs to be varied, and scheduled in advance.

**(D)** *Documenting* is important to record the animal's response to enrichment initiatives. Simple records of whether an animal uses the enrichment are currently the commonest form of documentation. More scientific information on changes to the animals' time-budgets, and long-term physiological and behavioural data are recorded less often, given the time investment and resources needed. The development of multi-institutional databases is an essential next step for the future.

**(E)** *Evaluating* effectiveness uses such records and the clearly defined goals (see 'S') to determine the extent to which an enrichment is successful. Formal, objective assessments remain, however, an underutilized aspect of all enrichment programmes.

*Continued*

**(R)** The final step requires *readjustments* so that enrichment initiatives remain (or become) effective. For example, enrichment can succeed or fail for many reasons – depending on which animal it is given to, in the presence of which conspecific, where, or at what time. Some may simply fail to evoke the desired behavioural response. Creativity, knowledge of the individual animals, and a clear understanding of behavioural goals are the keys to success here.

As a process, SPIDER ideally guides the implementation of knowledge on a day-to-day basis, to realize the true value of enrichment. It is a long way from the scientific experiments reported in Chapters 2–8 of this book, but still represents a major advance, and perhaps could even yield future data for further meta-analyses like those presented in this chapter.

Positive effects of appropriate enrichment are frequently found. In research laboratories, animals reared in more enriched environments show a variety of brain changes, demonstrate improved learning ability, and are less emotionally reactive and more exploratory with novel objects and places (e.g. Renner and Rosenzweig, 1987; and see Chapter 7). Animals living in enriched environments may also exhibit lower levels of pituitary-adrenal activation, and other indices of stress (Dantzer and Mormede, 1981; Carlstead *et al.*, 1993). Finally, enriched environments can promote a more diverse species-typical behavioural repertoire and a concomitant reduction in stereotypies (see previous chapters, and reviews in Shepherdson *et al.*, 1998). This suggests a clear role for enrichment in maintaining Q3 wild species in captivity, promising to increase successful mating and rearing of offspring, and to promote the development of more behaviourally competent candidates for reintroduction to the wild.

## 9.3. Reducing Stereotypic Behaviour with Environmental Enrichment: Principles Underlying the Practice

As discussed in this book, there are a number of potential causal factors in the development of stereotypic behaviour. Although all could be invoked to explain cases of stereotypy in zoos, some are probably more relevant than others. Some stereotypies in zoo animals doubtless stem from CNS pathology due to factors such as abnormal development (cf. Chapters 6 and 7); while others may occur as a direct consequence of veterinary health problems (e.g. dermatitis-induced stereotypic grooming, Virga, 2003; see also Chapter 10). However, zoo stereotypic behaviours are typically considered to be induced by an animal's current environment, and via the following potential causal factors:

*1. Frustrated motivations to perform specific behaviours*

Hughes and Duncan (1998) proposed that animals may suffer, and develop Q4 stereotypies, in situations where they are motivated to perform behaviours but are frustrated from performing them (see also Box 1.1, Chapter 1; and Chapters 2–4). They focused on appetitive behaviour, i.e. behaviour patterns that precede and enable an animal to acquire a certain resource or attain a particular state (such as access to a conspecific, a resting place, a cooler microclimate or food). However, frustrated consummatory behaviour, e.g. ingestion, can also be important. For instance, high levels of feeding motivation associated with insufficient nutrient intake can, quite independently of opportunities to perform foraging behaviours, lead to stereotypy performance (e.g. Rushen, 2003; see Chapter 2). In this case, both the stereotypy and the behaviours directed to effective enrichments often seem to be analogues of the specific frustrated natural behaviour (e.g. Shepherdson *et al.*, 1993; Swaisgood *et al.*, 2001; see also Box 1.1, Chapter 1).

*2. Paucity of behavioural opportunities*

Zoo environments have traditionally provided few challenges, leaving animals with large amounts of free time and no appropriate behaviour with which to fill that time (e.g. Carlstead, 1996). This may cause or enhance stereotypies either through reduced behavioural competition (due to few competing activities; see e.g. Chapters 2 and 4, on 'channelling'), or by encouraging animals to perform stereotypies to self-stimulate, e.g. to increase arousal to some optimal level (see Berkson and Mason, 1964; Mason, 1991).

*3. Lack of sensory stimulation*

Zoo environments may offer relatively little to *perceive* as well as to *do*; furthermore, the stimulation they provide may be very unvarying and predictable (see e.g. Chapter 7). Animals in such stimulus-poor environments may either reduce activity and stimulus-seeking behaviour, or seek out stimulation, again perhaps through stereotypy (e.g. Carlstead, 1996). Furthermore, repeated behaviours may become more stereotyped in form if the environment does not cause them to be varied (again see Chapters 2 and 4, on 'channelling').

*4. Stress*

Stress is defined by (i) the animal's perception of a threat that challenges internal homeostasis and (ii) the behavioural and physiological adjustments that the organism undergoes to avoid or adapt to the stressor and return to homeostasis (Moberg and Mench, 2000; and see Chapter 8). Several aspects of the zoo environment may be a source of stress to zoo animals. Humans, nearby predator species (e.g. Carlstead *et al.*, 1993), confinement with potentially aggressive conspecifics (Wielebnowski *et al.*, 2002a), and ambient noise levels (Owen *et al.*, 2004) all cause signs of stress. This may be exacerbated if the animal has no control over its exposure to stress, nor any other means of coping. Stress may result when animals do not have control over salient environmental factors, either reinforcing or aversive, i.e. where access to resources and even stimulus feedback is no longer *contingent* upon behaviour (e.g. Sambrook and Buchanan-Smith, 1997; Markowitz and Aday, 1998). Increasing the degree of control animals have over their environments may thus be one mechanism by which more complex environments tend to reduce stress and result in psychologically healthier animals (Wemelsfelder, 1993). Cabib (see Chapter 8) discusses one way in which stress may cause stereotypies. A further, functional hypothesis for a link between stress and stereotypies is that paradoxically, animals under stress may stereotype to reduce arousal to an optimal level (e.g. Mason, 1991; Carlstead, 1996; Mason and Latham, 2004; also see Chapter 6).

Based on these putative causal factors, a number of enrichment 'strategies' have evolved to guide efforts to reduce stereotypic behaviour. These strategies can be categorized as follows:

*1. Mimicking nature*

Almost a philosophical stance, this principle has long played a major role in zoo enrichment (e.g. Hutchins *et al.*, 1984). The aim is to stimulate natural behaviours or try to mimic specific environmental factors important in the wild (dens, food items, social groupings, increased space, etc.). The essence of this approach is that since species have evolved over many generations to survive and thrive in their wild habitat, mimicking nature should satisfy their motivational needs (see Section 9.3 (1), earlier). Mimicking nature could also affect stereotypic behaviour through the other mechanisms listed above. However, this is a 'scatter shot' approach: it does not really seek to address a specific frustrated motivation, but rather hopes that providing a more natural environment will satisfy psychological needs whatever they are. Veasy *et al.* (1996) outline the drawbacks of an overly simplistic application of this concept, especially if the implicit assumption is that everything in the wild is good for well-being. Since this is obviously not the case, we are generally left with little guidance as to which characteristics or behaviours of the wild environment should be mimicked and which should not, and therefore enrichment practitioners typically resort to informed intuition.

*2. Increasing the physical complexity of the environment*

Specifically increasing physical, and temporal, complexity – without necessarily mimicking nature – may add biologically relevant information to an animal's enclosure, resulting in increased opportunities for exploration and sensory stimulation, and perhaps alleviating sub-optimally low arousal (Renner and Rosenzweig, 1987; Carlstead, 1996). It can thus provide hitherto absent behavioural opportunities through increased diversity of substrates and physical structures. By providing a context within which an animal can learn to increase its chance of achieving a desired goal through the performance of appropriate behaviour it can potentially provide greater contingency or control (thence reducing stress).

*3. Increasing sensory stimulation*

If sensory stimulus deprivation is suspected, then modifications to the environment can be used to increase sensory stimulation *per se*

(Carlstead, 1996). Changes to the environment may be similar to those for increasing complexity, but greater emphasis is placed on stimulating the five senses. For example, scents can be introduced, noises made, visual complexity added (even video images have been tried), food varied in texture and/or taste and substrates added to provide varied tactile feedback. Social interactions may also function to increase sensory stimulation (e.g. via allogrooming, olfactory stimuli, etc.).

*4. Meeting specific frustrated motivations*

This principle is essentially a refinement of mimicking nature, but with the primary objective being to elicit the performance of specific behaviours. In practice, foraging behaviours are the most frequently targeted in this category. These are appetitive behaviours judged particularly likely to be important because they are essential for daily survival in the wild (thence likely to be highly motivated), and most species spend most of their waking hours foraging in nature. However, zoo animals often are fed highly prepared diets that do not allow them to employ natural search, acquisition and processing behaviours; and many observations do link feeding and foraging with stereotypies (e.g. Falk, 1977; Carlstead, 1996; Rushen, 2003; Young, 2003; and Chapters 2 and 3).

*5. Removing sources of stress or providing coping options*

In many cases the form and timing of the behaviour itself may indicate the source of stress or frustration and in these cases enrichment may consist of removing the stressor or providing the animal with a means of coping with the stressor. For example, leopard cats stressed by the close proximity of predators had lower corticoid and pacing levels when provided with appropriate hiding places (Carlstead *et al.*, 1993; see also Chapter 3).

*6. Providing enrichments that give the animal control*

Markowitz (e.g. Markowitz and Aday, 1998) is best known for pioneering this approach to enrichment. Over the years he and his co-workers have engineered numerous devices that re-establish contingency between behaviour and various consequences. As an example, food delivery can be made contingent upon the animal chasing artificial prey. This approach has been extended to include numerous other control options in the captive environment (also reviewed in Sambrook and Buchanan-Smith, 1997).

These categories of enrichment strategy are neither exhaustive nor mutually exclusive. A complex environment is likely, for example, to contain more options for control and coping with stress, to increase sensory stimulation, and to promote opportunities to perform behaviours that meet specific motivational needs. To the extent that the increased complexity is 'natural', complex environments may also mimic nature. Furthermore, multiple strategies often are implemented together (in an 'everything-but-the-kitchen-sink' approach). Thus isolating and understanding the effects of these different strategies is in practice a daunting task. Yet if we are really to understand how enrichment works and explain the differential efficacy between enrichment strategies, this must be done. In the literature analysis that follows, we have made a first attempt to do just this.

If implementing enrichments involves some challenges (see Box 9.1), then research on enrichments involves even more. Zoos are not primarily research institutions, and controlled experiments are challenging both practically and ethically (Swaisgood *et al.*, 2003b). Animals have to be available to display to the public, to undergo veterinary procedures and many other events that may jeopardize a closely controlled experimental design. Sample sizes are often small, and animals within an enclosure are not statistically independent. Also, it may not be ethical to continue with conditions that are clearly not helping or conversely to return to baseline conditions when the experimental condition has proved effective (see Chapter 10 for similar issues facing vets dealing with companion animals). However, in spite of these problems many attempts have been made and published to evaluate the effectiveness of enrichment in zoo animals. It is these we utilize below.

## 9.4. What can we Learn about Enrichment and Stereotypy from an Analysis of Published Zoo-based Research?

### 9.4.1. Our literature review and analysis: methods

A review of the literature can provide insights into how zoo practitioners tackle stereotypy with enrichment and move us one step closer to understanding what works in practice. Here we share results from a quantitative analysis of zoo-based published literature, and draw additional insights from the specifics of some case studies.

For this analysis, we reviewed all papers published between 1990 and 2003 in three peer-reviewed journals: *Animal Welfare*, *Applied Animal Behaviour Science* and *Zoo Biology*, where most peer-reviewed zoo enrichment studies are published. Where appropriate, we refer to studies published elsewhere, but the statistical analysis stems from only these papers, to avoid possible biases associated with the 'file drawer' approach (Lipsey and Wilson, 2001). We included only publications meeting the following criteria: (i) the animals were studied in two different situations that varied in terms of enrichment quality (i.e. control versus enriched); (ii) the performance of stereotypies was quantitatively measured and mean values were reported; and (iii) the study was conducted at a zoological park, aquarium or conservation breeding centre. Studies at biomedical research facilities were not included in this analysis (though see Box 9.3 for the types of insight they can generate). We found 18 publications meeting these criteria, but our sample size was increased to 23 because some papers included more than one study or reported results from two or more species. We refer to these 23 samples as 'studies'. This small number of peer-reviewed studies may seem disappointing, but this again speaks to the difficulty of carrying out first-rate research in a zoo environment.

**Box 9.3.** The Effects of Enrichment in Biomedical Facilities: Some Insights into their Effects on Laboratory Primates' Stereotypies

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In biomedical research laboratories, non-human primates are often kept in groups or pairs in indoor facilities, and more rarely, in individual cages, a housing treatment particularly linked with stereotypy (see Chapter 6). In these various conditions, which environmental enrichments reduce abnormal behaviour, and how might they act? Non-human primate data yield two take-home messages relevant to this chapter. First, very different forms of enrichments can be similarly effective at reducing abnormal behaviour. Second, sometimes some abnormal behaviours but not others are affected by a given enrichment.

To illustrate the first issue, in isolation-housed rhesus monkeys, self-directed abnormal behaviour can be reduced by exposure to a 'musical feeder box' (Line *et al.*, 1990), placement in an enriched playpen (Bryant *et al.*, 1988) and adding a conspecific companion (Eaton *et al.*, 1994); while stereotypic pacing and other whole-body stereotypies can be decreased by providing a foraging/grooming board (Bayne *et al.*, 1991), a food puzzle feeder (Novak *et al.*, 1998), or substantially larger novel cages (Draper and Bernstein, 1963; Paulk *et al.*, 1977). Similarly in group-housed rhesus monkeys, adding foraging opportunities (by scattering food in litter) to a standard cage, or increasing space allowance and climbing opportunities, both effectively reduce stereotypic pacing, and to equal degrees (Gimpel, 2005). Together, such findings suggest either that diverse enrichments share a common important feature, such as stress-reduction (see Chapter 8), or instead that different enrichments act to tackle stereotypies in varying, quite different ways (see this chapter for a list of likely means). Q5

Turning to the issue of differential effectiveness on different forms of abnormal behaviour, in three of the above studies of single-housed primates, enrichments successfully reduced whole-body stereotypies, but failed to affect the self-directed abnormalities such as self-injurious behaviour (Paulk *et al.*, 1977; Bayne *et al.*, 1991; Novak *et al.*, 1998). Similarly in group-housed rhesus monkeys, while extra space or foraging substrates reduced pacing, they failed to reduce body-rocking or self-directed behaviours (Gimpel, 2005). This finding could indicate that different types of environmental deficit are responsible for different types of abnormal behaviour, in which case trying yet further diverse types of enrichment should prove effective (see above for successful attempts to reduce self-directed stereotypies). Alternatively, it could indicate that some abnormal behaviours are inherently harder than others to tackle, perhaps because they are pathologies induced by early experience rather than direct products of the current environment. Note, however, that even such pathologies may slowly respond to changes in housing, when these changes are sustained and appropriate (see Chapter 6).

Before proceeding, some caveats on the analysis are necessary. First, some of our data are not fully independent, for example, when two or more species are given the same enrichment test at the same facility. Second, our sample does not come from a random sample of zoo animals, but instead emphasizes carnivores (6 ursids, 5 felids) and primates (5), with 6 others coming from disparate taxa (3 seals, 1 elephant, 1 giraffe and 1 conure). It seems likely that these species are either more prone to stereotypy or that zoo biologists are more concerned about their welfare – a form of 'targeting' that we return to later in this chapter. Third, the sample sizes for these studies are small (median = 4, range = 1–11). Fourth, a further shortcoming is that many studies used several different forms of enrichment simultaneously: often a veritable laundry list of enrichments is used. Such approaches can offer little insight into the underlying basis for stereotypy performance and its alleviation – they often address all four putative causal factors underlying stereotypy, and indeed this is probably precisely why such tactics are chosen. And herein lies the conundrum for zoo-based research on enrichment: zoo practitioners, generally speaking, are looking out for the welfare of their own animals first and foremost, and often the solution to 'problem behaviours' must be found quickly. These priorities do not lend themselves to the kind of careful experimental designs that tease out the various hypotheses to explain stereotypy and the effects of enrichment. Thus in our sample, 13 of 23 studies suffered from the use of many diverse enrichments, making our task of identifying 'what works and what does not exceedingly difficult.

To obtain a comparable dependent variable, we took the following approach. Data reported in the original articles were in the form of simple per cent time stereotyping before and after enrichment, which we used to calculate the per cent change in stereotypy to standardize the measure (see Box 9.4 for some relevant measurement issues here). Thus, a reduction in stereotypy from 4% time to 2% time would be equivalent to a reduction from 10% to 5%. This method is analogous in form to calculation of 'effect size' using standard literature meta-analysis techniques (Lipsey and Wilson, 2001), with the exception that we did not correct for bias arising from varying sample sizes in different studies. The formula for this correction requires knowledge of the standard error, which was reported in only a subset of the papers in our review. However, because paper sample sizes in our analysis were small and varied little, giving each study equal weight in the analysis probably introduces little bias. Although some authors reported different forms of stereotypy (e.g. locomotor, oral, repetitive movements), many reported results on composite stereotypies – an amalgamation of several stereotypic forms. While clearly much is to be learned by an analysis of stereotypic forms that may vary in underlying motivation (e.g. Mason, 1993; see also Chapters 2–4), our data therefore did not permit this. Thus, all forms of stereotypy were lumped for analysis.

Our independent variable of interest – enrichment type – was categorized enrichment according to the following dimensions. First, to evaluate whether enrichment targeted at feeding motivation was more effective, we categorized enrichment as feeding only, non-feeding only or a mix of both. Examples of non-feeding enrichment include enclosure modifications and provision of manipulable objects. Within the category of feeding enrichment, we classified the enrichment further by what kind of foraging behaviour was promoted – searching, extracting or processing. Second, we tried to determine which enrichment strategies worked better than others. We originally discussed six enrichment strategies or principles used in

**Box 9.4.** Evaluating Stereotypy Frequency in Enrichment Studies: Different Methods Lead to Different Conclusions

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Studies to determine the effect of environmental enrichment on stereotypies can differ in how they evaluate stereotypy frequency. For example, stereotypy might be measured as a proportion of all observations made across all hours ('Method 1') (e.g. Carlstead *et al.*, 1991; Shepherdson *et al.*, 1993; Grindrod and Cleaver, 2001); as a proportion of observations made during the period immediately after providing the enrichment ('Method 2') (e.g. Bloomstrand *et al.*, 1986; Powell, 1995; Tepper *et al.*, 1999; Swaisgood *et al.*, 2001: in these studies, observation periods ranged between 30 min and 2 h after providing enrichments); or as a proportion of all observations, controlling for the time an animal spends interacting with the enrichment ('Method 3') (e.g. Swaisgood *et al.*, 2001; Vickery, 2003). But do these three methods lead to the same conclusions?

Data were collected during an enrichment experiment involving 14 individually caged bears (8 Asiatic black bears (*Ursus thibetanus*: 4, 4,), and 6 Malayan sun bears (*Helarctos malayanus*: 4, 2,) ), and analysed using these three different methods (Vickery, 2003). The enrichment experiment comprised five stages: 'Pre' – a 10-day pre-enrichment baseline; 'Ob1' – a 7-day object-only enrichment stage (e.g. cage furniture, heavy-duty plastic containers, straw); 'Ob+fd' – a 7-day stage of object (as 'Ob1') plus food enrichment (e.g. whole coconuts, hidden food); 'Ob2' – an exact replicate of 'Ob1' and 'Post' – a 10-day post-enrichment baseline. During each stage, the bears' behaviour was observed between 0700 and 1800 h by scan-sampling from observation hides.

The three different methods of evaluating changes in stereotypy led to quite different conclusions as to the enrichments' effectiveness. When the measure used was total daily stereotypy (Method 1), only object enrichments had a near significant effect, and only during their first week of provision (GLM for 'Ob1' versus baseline: $F_{1,11} = 4.51$; $P = 0.057$). When only stereotypy in the first hour after enrichment presentation was considered (Method 2), only foraging enrichments were effective (GLM for 'Ob+fd' versus baseline: $F_{1,11} = 9.09$; $P = 0.012$). When stereotypy was assessed controlling for time spent using the enrichments (Method 3), no effects at all were found. Therefore, these three different methods of evaluating stereotypy clearly measure quite different things, and rank the enrichments differently. Differences between Methods 1 and 2, and Method 3 probably arose because only the latter controls for effects due to time occupation/behavioural substitution, while differences between Methods 1 and 2 are probably due to Method 2 overemphasizing the efficacy of enrichments that are used most when first introduced. However, it is not clear which of these methods reveals the most about an animal's welfare; and these results also suggest that it will often not be valid to compare enrichment studies or attempt to draw general conclusions from them if their methods of quantifying stereotypy frequency differ.

practice: mimicking nature; increasing environmental complexity or sensory stimulation; enabling specific motivated behaviours; reducing stress and giving animals control or contingency. These were based on the motivational principles discussed in Section 9.1. Of these categories, only four were amenable to analysis, however, two – (5) removing the source of stress and (6) providing enrichments that give animals control – were excluded because they occurred too infrequently and/or it was difficult to determine the degree to which they applied to a given study.

We evaluated each of the 23 studies, ranking them on a four-point scale for the four remaining categories:

**1** *Mimicking nature*. By far the most frequent principle alluded to in the zoo enrichment literature is the need to model captive environments after the stimuli and behavioural opportunities present in nature. We tried to estimate the extent to which the captive environment mimicked what would be found in the wild for the species.

**2** *Increasing environmental complexity*. Often enrichment practitioners attempt to make the environment more complex, varying the number and types of objects, stimuli and behavioural opportunities, without paying much attention to what is 'natural'. Indeed, practitioners may hope that artificial items serve as a functional analogues for more natural ones (Forthman-Quick, 1984; Swaisgood *et al.*, 2003a). Complexity is difficult concept (Sambrook and Buchanan-Smith, 1997). One method is to sum the number of 'features' it takes to describe the enclosure, but this only yields a facade of quantification. We took a more subjective approach, summing the enrichment changes that appeared to increase biologically relevant aspects of the environment. On a practical level these aspects were the only ones regularly described by authors. Indeed given the problem of quantifying complexity, Sambrook and Buchanan-Smith (1997) conclude that 'a subjective estimate is probably sufficient' (p. 208).

**3** *Increasing sensory stimulation*. This category overlaps somewhat with (2), but the emphasis is on providing multiple stimuli for different sensory modalities. Several studies scored high in (2) but low in (3), suggesting redundancy was not too problematic in practice.

**4** *Enabling highly motivated natural behaviours*. Most examples here dealt with attempts to increase foraging behaviour. For analysis, we evaluated studies based on how much animals were challenged to work for food, in terms of effort expended by the animals (see also our previous paragraph on feeding and non-feeding enrichments).

We analysed the effects of enrichment type with a two-way ANOVA, with enrichment category as one factor and taxonomic group (carnivore, primate, other) included as a blocking variable to reduce any statistical noise or confounding effects of phylogeny (see e.g. Box 3.2, Chapter 3). Our results are given below. Note that because of the limitations to our data-set, these are presented in the spirit of exploration, hopefully driving future hypothesis-generation and testing.

### 9.4.2. Results I: what kinds of enrichments were used?

As we noted in our methods, zoo enrichment practitioners often used a diverse array of enrichments. Below we describe briefly some of these enrichments before proceeding to the analysis.

In one type of enrichment commonly used, major permanent changes to exhibits were made or altogether new exhibits were built. Often live vegetation such as grass, bushes and trees were planted extensively or other naturalistic items such as logs, stumps, branches, stones, rock ledges, artificial vines, wading pools, substrate (e.g. leaves, dirt) and so forth were added. These sorts of enhancements allow animals to climb, explore, dig, dirt-bathe and generally stimulate sensory input and provide opportunities for physical exercise and locomotor play. They also give animals some basic choices, for example, to seek sun or shade for thermoregulation, to take cover from visitors or other nearby animals, or to seek a spot where they can view potential threats from a safe position above ground (see Forthman *et al.*, 1995; Poole, 1998).

The second common type of enrichment was the provisioning of manipulable objects, usually on a temporary basis. Different objects, such as plastic balls, fresh branches, egg cartons, cardboard boxes and so forth are rotated through the enclosures on an irregular basis. Feeding enrichments, the last main type used in zoos, were similarly diverse. Generally speaking, the design attempted to encourage one or more aspects of natural foraging behaviour. Some were designed to increase the amount of time the animal spent searching for the food, for example, by scattering the food around or hiding it under or on top of objects in the enclosure. For predators, live or simulated prey were used to stimulate capture behaviour. A number of clever methods were used to increase opportunities for animals to extract their food. Small food items were placed in puzzle feeders – hollow wooden or plastic objects with holes – forcing the animal to manipulate the feeder to get the food to fall through the holes. Food may also be frozen in ice blocks, requiring the animal to bite away the ice to get to the food. In one case, chimpanzees were given honey pots with 20 different tools such as string and wire brushes, used to extract the honey in a task designed to mimic the 'ant-fishing' behaviour seen in nature (Celli *et al.*, 2003). Finally, some enrichments were designed to enhance the handling and processing behaviours occurring just before consumption, for example, by adding browse or whole carcasses to the diet.

As we mentioned briefly in the methods, many zoo enrichment practitioners used a wide variety of these enrichments simultaneously. This 'everything-but-the-kitchen-sink' approach can produce dramatic results. In one example (Grindrod and Cleaver, 2001), enrichments for common seals included bottles, boxes, balls, trays, buoys, wood blocks, ice blocks, mirrors, water spray, fountains, music, floating mats, islands, fish pulled across the water and self-propelled bottles containing fish. Most of these were given with and without fish hidden in or around. It is not surprising that these enrichments effected a reduction in stereotypy from about 65% to 23% of the animals' time. Clearly this strategy worked well in this case. It is also an example of the creativity and energy used to recreate environments for zoo animals. But what aspects of it, specifically, worked? It is difficult to determine. Was it mostly due to the wood blocks? Were hidden fish the key? This is a good example of excellent enrichment, but with a relatively poor transfer of information to other facilities hoping to improve the welfare of their animals. Short of reproducing the entire programme, one does not learn how to use enrichments to achieve the desired effect.

Our hunch had been that such pragmatic 'everything-but-the-kitchen-sink' approaches were most adopted when there was a large problem to be solved. This was confirmed in our data-set when we asked whether multiple and diverse environmental changes made simultaneously (e.g. was the whole enclosure renovated and altered in many ways?) or whether just a single strategy was taken (e.g. a single or set of similar feeder devices or manipulable objects added?). In the studies where many and diverse changes were made, animals performed stereotypies for significantly more time pre-enrichment ($N = 13$, mean = 26.4%) than in studies where only few changes were made ($N = 10$, mean = 7.9%, $F_{19} = 4.8$, $P = 0.04$). This suggests that enrichment practitioners throw more enrichment at animals displaying greater stereotypy problems.

### 9.4.3. Results II: how well did enrichments work?

The most important question to begin with is, simply, does zoo enrichment work? Our cross-study analysis of effect size shows that – at least in these published studies – zoo enrichment works and it works quite well (Fig. 9.1; repeated measures ANOVA: $F_{1,20} = 20.6$, $P = 0.0002$ with Greenhouse–Geisser adjustment to correct for correlation of repeated measures). Among carnivores, primates and other species, a reduction in stereotypy performance of between 50% and 60% was observed following the onset of the enrichment programme. However, it is also essential to point out that in no case was stereotypy completely abolished.

One possible concern is that these observed effects may be merely short-term, and that once the novelty has worn off, the stereotypy levels will return to pre-enrichment levels. If this is the case, our results will overstate the real

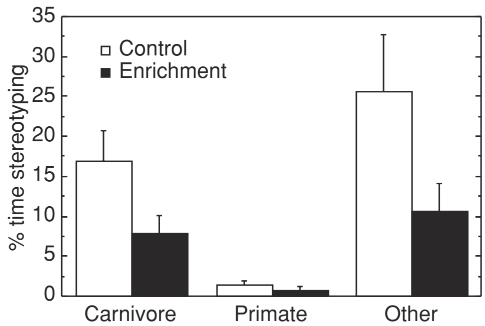


**Fig. 9.1.** Zoo enrichments significantly reduce stereotypy performance in various species. *y*-Axis values represent the mean of study means (for all individuals included in the study) for per cent time spent performing stereotypies.

effectiveness of enrichment. To test this notion, we reasoned that studies of longer duration should give subjects more time for habituation. However, we found no such negative relationship between study duration and per cent change in stereotypy following enrichment. In fact, we found the opposite i.e. that longer studies were associated with greater enrichment efficacy, although this effect was marginally non-significant ($r^2 = 0.17$, $P = 0.06$; median = 4.5 months; range = 0.5–16 months). These results indicate that the enrichment effects were fairly robust to habituation, perhaps because so many enrichments were comprehensive in scope (see earlier).

### 9.4.4. Results III: did some kinds of enrichment work better than others?

#### *9.4.4.1. Feeding versus non-feeding enrichments*

Of equal importance is to determine what *kind* of enrichments work. Although this may vary with taxon (see below), it is instructive to take a first look across all the species in our sample to see if any certain class of enrichment stands out. This is justifiable because most of the theories for why enrichment reduces stereotypy apply to most species. This may provide insight into generalized underlying factors associated with stereotypy performance in zoo animals.

As discussed above, this analysis was compromised by the fact that in many studies several different forms of enrichment were given. One comparison we can make without such obfuscation is between enrichments that were based on feeding, non-feeding or a combination of both. Each study can be clearly classified into one of these three categories. Given the predominance of the concept of feeding motivation in stereotypy performance and enrichment, one might predict that enrichments with food are more effective than those without.

In our sample, however, this was not the case (Fig. 9.2). Feeding, non-feeding or a combination of the two were all equally effective at reducing stereotypies, in each case by 56–58% ($F_{3,15} = 0.48$, $P = 0.63$). Although taxonomic group was included in the model as a blocking variable to reduce taxon effects on the results, it is possible that some taxa were more likely to receive feeding enrichment than others. However, Table 9.1 suggests that this is not the case, with carnivores, primates and other orders being equally likely to 'attract' feeding enrichment from their caretakers. It may still be the case, however, that caretakers are tailoring their enrichments to suit the problem they are trying to solve – an issue we return to.

#### *9.4.4.2. Feeding enrichment: a closer look*

Analysis of more specific details of enrichment strategies may uncover some patterns. To examine this possibility, we further categorized each study of feeding enrichment according to the type of behaviour promoted: search, extract, process or mixed. It is also possible – in most cases – to

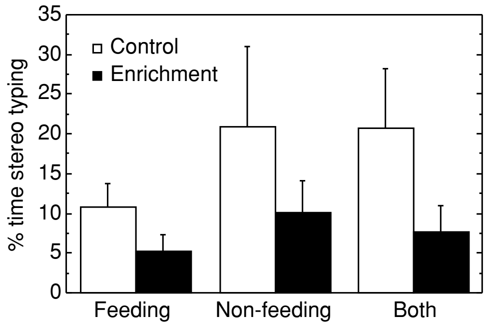


**Fig. 9.2.** Enrichments with and without food did not differ in terms of their effectiveness in reducing stereotypy performance.

determine whether feeding enrichment involved a change in the actual diet or just a change in the presentation of food.

Examination of Fig. 9.3 suggests that the type of feeding task may affect its success at reducing stereotypy levels, with extraction behaviours being less successful at reducing stereotypies. However, all extraction tasks were given to primates (Table 9.2), so feeding task is confounded Q6 with taxonomic order. From this we can see that in the three cases in which feeding enrichments were given to primates – all extraction tasks – they performed poorly. By contrast, in the remaining studies where primates were given non-feeding enrichments (major exhibit changes), there was almost 90% reduction in stereotypies. However, these studies with primates are particularly difficult to interpret because pre-enrichment levels of stereotypy fell in the range of 1–3% of the total activity budget, far less than for other groups (see Figs 9.1 and 9.4): thus taxon and prior stereotypy level were confounded. Similarly, all search tasks were given to carnivores, thus again confounding feeding task with taxonomic group. Thus overall, it is unsurprising that the statistical model which controls

**Table 9.1.** The frequency with which different taxonomic groups received feeding and non-feeding enrichment or a combination of both.

| | Feeding | Non-feeding | Both | Totals | |
|---|---|---|---|---|---|
| Carnivore | 8 | 3 | 0 | 11 | |
| Primate | 3 | 1 | 2 | 6 | |
| Other | 2 | 0 | 4 | 6 | |
| Totals | 13 | 4 | 6 | 23 | |
| | Search | Extract | Process | Mixed | Totals |
| Carnivore | 4 | 0 | 1 | 2 | 7 |
| Primate | 0 | 3 | 0 | 0 | 3 |
| Other | 0 | 0 | 2 | 0 | 2 |
| Totals | 4 | 3 | 3 | 2 | 12 |

for such taxonomic effects, does not even approach significance for the effects of feeding task on enrichment efficacy ($F_{2,7} = 0.53$, $P = 0.61$).

To understand fully how feeding enrichments influenced stereotypy performance it is necessary to know whether these enrichments involved a dietary change or whether diet remained unchanged while opportunities for feeding behaviours changed. The observed effects of any feeding enrichment may result from improved nutrition, meeting ethological needs to forage or both. Unfortunately, the authors did not always state whether food used in enrichment involved a change in diet, so it was impossible to test this. To distinguish between nutritional and ethological needs hypotheses it will be necessary for authors to report changes in diet. Even so, there will be many instances where nutritional and behavioural changes of will occur together for many feeding enrichments. For example, Stoinski *et al.* (2000) replaced the normal feed for elephants, Bermuda hay, with an equal dry weight of natural browse, which dramatically changes both diet and foraging behaviours (cf. Chapter 2). This experimental constraint will be common in most studies designed to increase the processing component (see below) of feeding behaviour, whereas increasing search and extraction time can be easily manipulated without changing diet. Thus, the role of processing behaviour, such as handling and mastication, will be more difficult to distinguish from nutritional needs. Future studies should strive to change the amount of processing work without changing nutritional content.

#### *9.4.4.3. The role of enrichment strategies*

As outlined in Section 9.1, enrichment could address four potential causes of stereotypy – sustained motivations to perform specific behaviours; the paucity of behavioural opportunities; a lack of sensory stimulation and stress. As a result of this there are several enrichment strategies

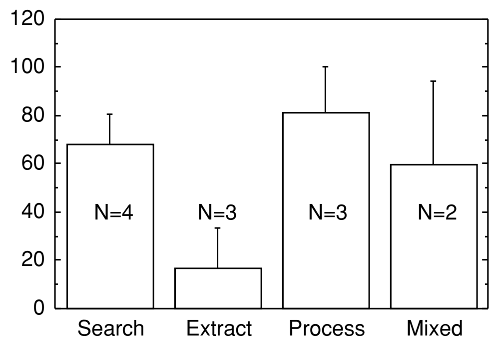


**Fig. 9.3.** Enrichments promoting different forms of foraging behaviour did not differ in terms of their effectiveness in reducing stereotypy performance. Although extraction of food appears least effective here, this effect can be explained more parsimoniously by taxonomic effects (see text). (The *y*-axis = % change in stereotypy).

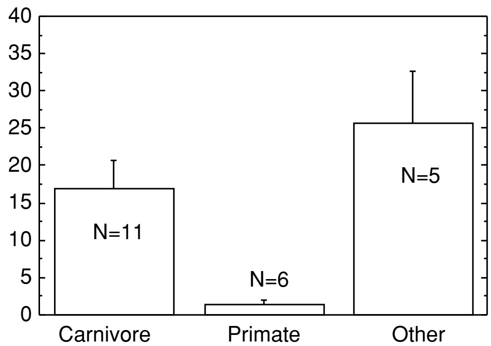


**Fig. 9.4.** Baseline proportion of time spent performing stereotypies before enrichment manipulations for different taxonomic groups.

or principles used in practice: mimicking nature; increasing environmental complexity or sensory stimulation; enabling specific motivated behaviours; reducing stress and giving animals control or contingency. Of these six categories, we could assess the first four.

There are several caveats. Although we tried to be as objective and consistent as possible when ranking studies according to these principles, there is inevitably a subjective component to how studies were scored. Since the studies were not designed to manipulate just one of these principles/strategies, we cannot compare a relatively pure manipulation of ethological needs with a relatively pure manipulation of physical complexity. Therefore, the tests that follow compare one type of enrichment to the combined effects of all other forms of enrichment in the sample, not to control or to baseline conditions. Surprisingly, our analysis found no association between the evaluated scale of any of the four enrichment principles and the per cent change in stereotypy (ANCOVA with taxon as blocking variable: $F_{1,18}<0.74$, $P>0.41$). Even studies rated highly across several principles did not fare better than those with low ratings. The fact that none of the tests even approached significance suggests that these measures of enrichment properties have little bearing on how effective enrichment is at reducing stereotypy. Alternatively, researchers could have tailored the enrichments to the specific problems seen in their study subjects, an issue we return to later.

### 9.4.5. Results IV: taxonomic effects on enrichment and stereotypy revisited

Do some taxonomic groups spend more time performing stereotypies than others? Clearly, different species have markedly different evolutionary histories, biological make-up, life history characteristics and behavioural temperaments. To the extent that these characteristics are shared by related species, we might find that some groups are prone to perform stereotypy at higher levels (see e.g. Chapter 3 on carnivores). It certainly appears that taxa differ in their typical forms of stereotypy, as we saw in Chapter 1, Fig. 1.2. For this analysis, we examined only the data for pre-enrichment periods, and found that taxon did significantly affect stereotypy performance ($F_{3,20} = 6.0$, $P = 0.009$; Fig. 9.4), with primates being the least stereotypy-prone in our sample. Among the carnivores, cats spent more time stereotyping than bears (22.6% versus 12.4%) (see Chapter 3 for a more detailed analysis of species-differences within the Carnivora).

One might speculate that the social housing arrangement prevalent for primates makes them less vulnerable to stereotypy development (see Chapter 6), but the 'other' group also contained mostly socially housed animals that also displayed high stereotypy levels. Further speculation on potential taxon-specific causes of stereotypy seems imprudent with this limited data-set, though.

By contrast, these taxonomic groups did not differ in their response to enrichment. We found no differences in the per cent change in stereotypy levels from pre-enrichment control periods to enrichment ($F_{3,19} = 0.29$, $P = 0.75$; Fig. 9.5). Enrichment effected a 50–60% reduction in stereotypy performance for each of the three taxonomic groups. Thus, we conclude that enrichment as currently used is effective regardless of taxonomic affiliation, and also that pre-enrichment stereotypy levels do not determine how effective enrichment will be.

## 9.5. Conclusions and Directions for Future Research

What lessons can we learn from this first, and somewhat preliminary, systematic analysis of the zoo literature on stereotypy and enrichment?

First, our results suggest that environmental enrichment does effectively reduce stereotypy in zoo animals, at least in those studies that are published in refereed journals. The good news was that in our sample, enrichment on average halved the time spent performing stereotypies.

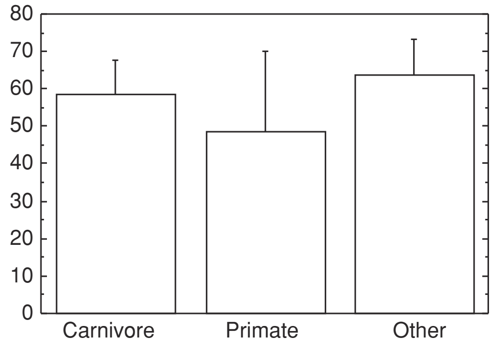


**Fig. 9.5.** The per cent reduction in stereotypy performance following enrichment in different taxonomic groups.

Clearly zoo enrichment practitioners are doing something right, and one cannot help but be impressed by the creativity and diversity of effort found in these enrichment programmes.

With such dramatic reductions, this result also offers great promise, by suggesting that most stereotypies in zoos are not yet neurally 'hard-wired' and that they are still responsive to positive environmental change – even though subjects were typically adult animals with pre-existing stereotypies (cf. e.g. Chapter 7; see Mason and Latham, 2004; see also Chapter 10).

Furthermore, as far as we could tell, such effects were not just transient and just due to novelty alone. Indeed longer-lasting enrichments tended to have greater, not lesser effects. This could be because longer-lasting enrichment studies may have been better planned and executed, given the long-term investment, or perhaps because some stereotypies are resilient to enrichment and the cumulative effects of long-term enrichment produce stronger effects.

However, a third finding, lest we be too joyful in our successes, was that in no case was stereotypy completely abolished. This may indicate that the enrichments used were always insufficient to tackle all underlying motivations to perform stereotypies. Perhaps we still do not understand fully the underlying motivations for stereotypy in zoo animals. Or alternatively, could stereotypies be both easily influenced by environmental context yet *not* be fully extinguishable because of some neural habit, or form of CNS dysfunction (cf. Chapters 5–8)? The answer to this question seems unknown. Stereotypy abolishment, though rare, has been reported (Mason, 1991), but there has been no systematic effort to evaluate the context in which abolishment occurs. Large-scale change in basic husbandry and environment is the most likely candidate to reduce stereotypies to nil in zoo environments. In one instructive example, a male giant panda was moved from a small, relatively barren pen to a larger, more naturalistic pen under completely different feeding and animal care management, including a supplemental enrichment programme. Before this environmental transformation, this male spent more than one-third of his time pacing, but ceased pacing permanently (for at least 7 years) after the change (R. Swaisgood, unpublished data). However, another male underwent a similar transition to a new and improved environment, yet persisted in his tongue-flicking stereotypy. Are some forms of stereotypy more easily abolished than others? (See Box 9.3 for similar examples from laboratory primates). Or do individual temperament, developmental history, etc. explain these divergent anecdotes? Again, these zoo data highlight some important unanswered research questions.

Our fourth main finding was that no type of enrichment seemed to be more successful than any other. For example, we could find no evidence that feeding enrichment was any more effective at reducing stereotypies than non-feeding enrichment; and there are within-study examples, too, where the two approaches were equally effective at reducing stereotypy (e.g. Swaisgood *et al.*, 2001). We also hypothesized that the type of feeding behaviour (e.g. searching, extracting, processing) promoted by feeding enrichment might determine its efficacy, and again our analysis failed to discover a relationship (although species differences in feeding behaviour may have influenced this result). Given the prominence that the role that feeding motivation and frustrated foraging is surmised to play in stereotypy performance, this finding is rather surprising. We made one last attempt to see if any universal factors were responsible for the efficacy of enrichment, by examining the importance of four prominent enrichment principles (mimicking nature, environmental complexity, sensory stimulation, foraging challenge). However, again we came up empty-handed, with enrichment strategies ranking high in one principle no better than strategies ranking high in other principles. It is rather disappointing that from this review, we have learned so little about 'which enrichments work and which don't'. So, what reasons could there be for this?

First, we should acknowledge that confounding variables and limited sample sizes greatly compromised our analyses. Thus, to give just one example, we could conclude little about the taxon-specific effects of different types of foraging enrichment. Or perhaps methods of scoring stereotypy affected the results, and thence added noise, as discussed in Box 9.4. Future surveys with larger sample sizes, and more equitable representation across taxonomic groups, would be required to investigate these issues adequately. A second possible reason is that none of the variables examined here are truly important in determining successful enrichment. We are reluctant to jump to this conclusion, but an alternative possibility could be merely that our schemes and scoring systems – sometimes based on rather limited data – failed to encapsulate or rank the properties of enrichment that really are differentially important to stereotyping animals. A third explanation for the apparently similar success of diverse enrichments is that all the variables examined here were equally valuable. Perhaps the most parsimonious conclusion is that more than one factor is causal in stereotypy performance. Thus animals may well be kept in conditions in which multiple factors give rise to stereotypies; for instance, conditions could both thwart opportunities to perform foraging behaviours *and* exploratory, stimulus-seeking behaviours. The box in this chapter (Box 9.3), on laboratory primates, also illustrates how diverse enrichments may be similarly effective at reducing stereotypies, presumably working via different processes. Indeed, in a further study, not reviewed by them, rhesus monkeys housed individually in small cages showed reduced corticoid levels and abnormal behaviours even when just given simple manipulable devices (Line *et al.*, 1991). Thus, in the most extreme situations, one might argue that 'something, anything' added to a stimulus-poor environment may have equally meaningful effects on stereotypy (and perhaps other indices of welfare).

Finally, it is plausible that enrichment practitioners selected enrichment intelligently based on the factors apparently operating in their own study animals. Thus enrichment practitioners may have tailored enrichment to individuals and existing conditions (see Mellen and MacPhee, 2001), as well as taxonomic group. Perhaps they successfully identified which animals needed feeding enrichment (e.g. those pacing at the door waiting to be fed), distinguishing them from those that needed more general enhancements in their environment (e.g. those kept in small, barren enclosures observed pacing at the cage boundary or displaying escape-related stereotypies). Such creative and appropriate tailoring of enrichment may obscure any universal patterns. If the enrichments chosen are tailored for maximum appropriateness, this could well explain why they all seemed to be similarly effective, and would clearly obscure any differential enrichment efficacy that might be seen if their use was more random. Indeed in our literature sample we occasionally came across authors that explicitly acknowledged such tailoring of enrichment to the observed stereotypy problem. For example, Baxter and Plowman (2001) provided giraffes with high-fibre meadow hay *because* the animals performed oral stereotypies, believed to be caused by frustrated feeding motivation (cf. Chapter 2). Furthermore, in our analyses we showed, for example, that 'everything-but-the-kitchen-sink' approaches were most likely to be adopted when stereotypy levels were high; and that food extraction enrichments were given to primates more often than to other taxa – again suggesting that the enrichments used in each study were selected on a tailored, case-by-case basis.

Finally, our fifth and last main finding from the survey was that different taxa varied in the amount of pre-enrichment stereotypy. Zoo primates showed low levels, a result nicely complementing the zoo and laboratory comparisons are given in Chapter 6. Carnivores, especially felids, showed high levels. As it stands we cannot say why – this could reflect biological differences between mammalian taxa, differences in typical housing or both – but future zoo research is ideally placed to investigate further.

So what can we conclude about the value of zoo work to the scientific understanding of stereotypies? It is clear that there are many obstacles. For example, practices like enrichment 'tailoring', and the use of simultaneously presented, multiple diverse enrichments, probably mean that while zoo researchers will continue effectively helping their animals, they will often contribute relatively little to understanding these behavioural phenomena. However, zoo data can still have real value. For one, the sheer diversity of species available for study at zoos could add tremendously to our understanding of phylogenetic effects on stereotypy, and allow the novel test of hypotheses (cf. Clubb and Mason, 2003). Thus zoo researchers have access to individuals with varying evolutionary histories, life history strategies, foraging strategies, ranging patterns, social systems and vastly different temperaments and perhaps behavioural needs. Furthermore, zoo animals often differ too in aspects of their early experience (see Box 7.1, Chapter 7).

So, which of these characteristics are associated with different forms of stereotypy and how do they respond to different housing arrangements, husbandry practices and enrichments? With an improved empirical arsenal, zoo enrichment practitioners stand ready to make major inroads in this arena. Zoo studies are also valuable because they highlight the research questions that impede the successful elimination of stereotypy. For example, how does one prevent the development of stereotypies in captive environments in the first place? Is prevention truly better than cure? Although zoos contain plenty of animals that have never performed stereotypies, no one to date has systematically analysed the factors responsible for stereotypy *development*. Future emphasis should be placed on how to abolish stereotypies altogether, something that did not occur in our sample, and which – as we saw earlier in this discussion – raised a number of questions about the causation of stereotypy.

This literature review and meta-analysis has thus yielded some new insights into stereotypies and enrichment, but also has been instructive in highlighting some of the shortcomings of zoo enrichment research and pointing to new directions that merit attention in the future. We would like to see a zoo literature that enables a better understanding of the *causation* and *motivations* underlying stereotypies, eventually allowing enrichment strategies to be shaped out of a *predictive* theoretical framework. If this can be achieved, the zoo community can greatly enhance its contributions to the larger fields of animal welfare and applied ethology. Below we enumerate several suggestions to facilitate this:

1. Study one or a few enrichments at a time, or otherwise allow the separate effects of each type of enrichment to be measured.
2. Test-specific predictions from motivational models attempting to explain stereotypy – for example by collecting additional data on stress levels (e.g. Swaisgood *et al.*, 2001; Wielebnowski *et al.*, 2002a; Mason *et al.*, in press).
3. Analyse the effects of enrichment when the subjects are not directly interacting with the enrichment, to determine whether it affects the motivation to perform stereotypies or just occupies animals' time (cf. Box 9.4).
4. Conduct studies aimed at understanding the environmental and biological factors underlying the development of stereotypies, for example by also looking at non- or low-stereotyping animals.
5. Conduct multiple-institutional studies that increase sample size and expand the generalizability of findings to various captive environments (cf. some equine studies; see Chapter 2). For experimental examples in zoos (see e.g. Mellen *et al.*, 1998; Wielebnowski *et al.*, 2002b; Shepherdson *et al.*, 2004), and for multi-institutional questionnaire surveys (Bashaw *et al.*, 2001).
6. Describe the form of stereotypies in detail, and analyse the effects of enrichments on different stereotypy forms separately. If individual stereotypy forms occur too infrequently to merit separate analysis, at least provide descriptive statistics (e.g. in table form) that may be used later in meta-analyses.
7. Examine the long-term effects of enrichments to rule out possible novelty effects, understand how to avoid habituation and reveal why long-term enrichments may be more effective.

**8.** Design studies to determine the circumstances in which stereotypies are abolished, not just diminished (even if this means using/reporting anecdotes).

**9.** Report negative and non-significant findings in the literature on the effects of enrichment on stereotypy, even if this means 'hitching' them on to more publishable positive results. Currently, only the successful enrichment studies are likely to be published.

**10.** Include low-stereotypers too. In evaluating our results, our sample probably represents some of the worst cases of stereotypy in the zoo community. It could be instructive (and potentially also valuable for welfare – see Chapter 11), if less 'alarming' subjects also merited large enrichment research projects.

**11.** Conduct further meta-analyses, incorporating non-journal data. To illustrate, a better idea of the full amount of effort going into enrichment is found in the numerous publications in unrefereed journals and conference proceedings (e.g. *Shape of Enrichment*, *AZA Proceedings; see also Box* 9.2).

Overall, we recognize that at times the goals of research and promoting well-being may run counter to one another in zoos. While on the one hand we advocate controlled studies to understand the individual effects of particular enrichments, we also acknowledge that the goal of optimal well-being and reproduction will only be achieved through more holistic approaches incorporating many varieties of enrichment into basic husbandry practices (Mellen and MacPhee, 2001; Swaisgood, 2004a). On the other hand, holistic approaches will continue to involve educated guesswork and 'everything-but-the-kitchen-sink' tactics, unless we fully understand the causes of zoo animals' stereotypies.

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