

CONTROL AND COMPLEXITY IN NOVEL OBJECT ENRICHMENT

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Abstract

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We discuss the properties of controllability and complexity in novel object enrichment, their definition and present a critique of previous work related to them. We address the relationship between control and complexity, the evolutionary basis of their attractiveness and suggest that the acquisition of control may be a more enriching process than its execution. We propose that, although little work has been directed at separating their relative contributions to enrichment, controllability appears more important than complexity. We discuss the ways in which objects can be responsive both in terms of the predictability of the response and the 'grade' of actor-object interaction.

Keywords: *animal welfare, control, complexity, enrichment, novel object, responsive*

Introduction

Research concerning the quantity and patterns of reactions of various species to objects hitherto unknown to them serves a number of theoretical and practical purposes. One of these is the study of how adaptation to a particular habitat governs a species' response to novelty. In their seminal study, Glickman and Sroges (1966) quantified the reactions of more than 200 zoo animals, in various taxonomic groups, to a standardized set of novel objects and found significant effects broadly related to species' ecology: carnivores and primates, for example, investigated more than herbivores. Since this pioneering work, and that of Jolly (1964), the special interest exhibited by primates towards unfamiliar objects has been used as a technique to investigate several aspects of their biology. For example, species differences in relation to social structure, territoriality and dominance (Fragaszy & Mason 1978; Chamove 1983; Millar *et al* 1988); species and sex differences in response to environmental change (Box 1984, 1988, 1991); cognitive abilities (Menzel 1965, 1978; Menzel & Menzel 1979); manipulative skills and problem-solving 'styles' (Parker 1974; Visalberghi & Mason 1983); anti-predator strategies and relationships between group size, vigilance and predation (Jaenicke & Ehrlich 1982; Caine 1984; Caine & Marra 1988).

In addition to the important theoretical implications of such research, there are also practical implications for animal management. These relate to the ways in which different species respond to physical attributes of their captive environment and how the quality of the captive environment can be improved by the introduction of unfamiliar stimuli. The majority

of enrichment attempts focus on increasing the complexity both of the physical environment and of the behavioural repertoire (eg McGrew *et al* 1986; Segal 1989) and a major, often implicit, objective to such enrichment techniques is to increase the animal's control over its environment. Novel object enrichment is now a standard technique (eg Bryant *et al* 1988; Chamove 1989; Line *et al* 1989, 1991; Bloomsmith *et al* 1990; Line & Morgan 1991; Adams *et al* 1992; Preutz & Bloomsmith 1992; Bayne *et al* 1993; Shefferly *et al* 1993; Chmiel & Noonan 1996), yet little is understood about what properties of objects constitute enrichment. In this paper we discuss two potentially enriching properties: complexity and controllability.

Complexity in novel objects

Experimental evidence suggests that there is a positive correlation between level of activity and environmental complexity (Tripp 1985). Dimensions of complexity include the presence of other animals, the presence of manipulable objects and the physical structure of the enclosure. More specific investigations which suggest that primates have a preference for complex stimuli come from the work of Humphrey (1972). In a series of experiments, he examined rhesus monkeys' (*Macaca mulatta*) visual preferences for stimuli (the presentation of which the monkey could control with a button) and found that, given a choice of two stimuli, the monkeys consistently showed preferences for the one which was more complex. This study by Humphrey (1972) refined earlier work showing similar effects by Butler (1954) and Sackett (1965, 1966).

However, whilst complexity is a concept that is freely used in the behavioural sciences, its quantification is problematic (Sambrook & Whiten 1997) and thus deserves some consideration when posited as a property underlying enrichment. In the information sciences complexity is typically defined as the quantity of information required to describe a system (Chaitin 1970), or in the present case, an object. Visual complexity can be quantified using the number of principal axes, ie parts that are longer than they are wide (Marr & Nishihara 1978) or in terms of 'geons' (a set of about fifty basic shapes, Biederman 1987). In both these cases it is the number of features that serves as an index of complexity. In practice, a subjective estimate is probably sufficient. The point we wish to make is that in assessing complexity, the boundaries of the system so quantified should be made explicit. Thus, visual complexity is a property of the object itself which should not be confused with, say, the complexity of interactions that it affords. In consequence, whilst Humphrey's (1972) study unambiguously measures the effect of complexity, Tripp's (1985) study does not since many other properties are included within the author's concept of 'environmental complexity'.

Control of novel objects

In contrast, controllability is clearly an interactive property. Operational definitions of controllability (ie those that enable it to be measured) revolve around the difference in likelihood of an event occurring depending on an animal's behaviour. If the animal's behaviour does not influence the likelihood of the event then the event is deemed uncontrollable (Overmier *et al* 1980). A number of authors have provided evidence that control is psychologically and biologically important to animals. Hanson *et al* (1976) showed that macaques who were able to control the occurrence of a noxious stimulus (white noise) showed lower cortisol levels than another group experiencing the same degree of exposure

but without control. Mineka *et al* (1986) demonstrated that giving infant rhesus monkeys control over aspects of their environment (such that there was a direct correspondence between their actions and some important change) led to a decrease in fear and an increase in exploratory and coping responses, compared to a group which lacked such control. Similarly, work by Markowitz and Line (1989) suggests that devices that an animal can control and that respond to them in some way, will be used by a larger proportion of animals and for a longer period of time, than devices or toys that are not actively responsive.

However, whilst environments that an animal has some control over are increasingly being described as an essential feature of good captive settings (eg O'Neill 1989; Markowitz & Line 1991) there remains a paucity of experimental work aimed at directly testing this hypothesis. The majority of empirical work on the effects of providing animals with control over aspects of their environments is concerned with control over punishment rather than reward (see Overmier *et al* 1980 for a review), for which behavioural dispositions may be different. In comparison with the behaviouristic tradition which used strictly empirical methods to illustrate assumed universal laws, the purpose of enrichment is pragmatic and concerned with practical implementation. Thus in some cases, such as that of Markowitz and Line (1989), control is provided regarding the procurement of food. This is ecologically valid and potentially enriching but begs the question of whether the animal is stimulated by the exercise of control *per se*, or by the need for calories, for, whilst control is a putative need for animals, food is a certain one. The two factors would have to be separated to demonstrate that the former was having any effect. 'Contrafreeloading' experiments have controlled for this possibility by allowing subjects the choice of working for food or obtaining it for 'free', and have produced surprising results. Early experiments were conducted by Stolz and Lott (1964), who showed that rats would run through a maze heavily strewn with pellets to obtain a single identical pellet at the location at which they had previously been rewarded. Neuringer (1969) demonstrated that pigeons would peck a disc repeatedly to obtain a food reward when the same food was easily obtainable in front of them. Many subsequent experiments have shown similar results, as reviewed by Inglis *et al* (in press).

However, do these observations indicate a desire to exercise control? By our earlier definition – the effect of behaviour on outcome probability – the answer is no, since, by performing the behaviour (ie running through the maze), the likelihood of reward occurring is actually lower (given wasted time) than when the animal performs other natural foraging behaviours when there is free food available. Explanations other than gratification from the exercise of control can be offered, for example that the operant response has acquired the status of a reward in its own right (eg Alferink *et al* 1973), or that the behaviour corresponds to some natural foraging drive, normally denied in captivity (Anderson & Chamove 1983). Whilst, contrafreeloading experiments showing the preference for response-dependent food have at least used reward rather than punishment, the relevance of rats in mazes and pigeons in Skinner boxes to the enrichment endeavour is questionable. In a welfare context the behaviours described above could be viewed as stereotypes rather than the animal exercising control. However, more recently, Inglis and Ferguson (1986) and Inglis *et al* (in press) have advocated that contrafreeloading be interpreted as a form of exploration on the part of the animal and an assessment of currently sub-optimal food sources that may in the future

become optimal. As such, further research into contrafreeloading may contribute to ecological approaches to the provision of enrichment, the subject considered below.

Ecological approaches to the provision of control

The attractiveness that the ability to control holds for animals should not surprise us since control is *the* adaptive aspect of behaviour: control over what you eat, what eats you (within certain limitations), with whom you mate, etc. It is fair to describe the process of learning as acquisition of control through the learning of rules, be it the colour and scent of fruit when it is good to eat, or a newborn learning to walk through discovering the rules governing momentum, its own bio-mechanics, etc. Object play during development (human and non-human) serves an exploratory function (Piaget's 'tertiary circular reactions' 1959), enabling individuals to establish control over the mechanical affordances of objects.

The adverse effects of perceived lack of control, such as apathy and learning inhibition, are well-documented and discussed, most notably by Seligman (1975). At the opposite extreme however, total control, particularly over trivial processes, cannot be expected to alleviate boredom and may even encourage new undesirable behaviours not normally present in the species. For example, in Markowitz and Line's (1989) enrichment study one macaque pressed a control switch 130,000 times in one week to obtain food rewards. Clearly this must interfere with any kind of normal macaque activity-budget.

Some of the most fulfilling activities that humans partake in involve treading a line between the boredom of total control and the anxiousness associated with absence of control (Csikszentmihalyi 1975), a pursuit Jeremy Bentham described as 'deep play' (Crook 1980). Humans appear actively to seek out opportunities for such deep play.

How can the would-be enricher best steer a course through these two undesirable extremes of control? One possibility would be to provide 'semi-controllable' enrichment devices that do not always respond. This, however, would be to confuse the properties of controllability and predictability (a confound which Overmier *et al* (1980) have addressed). Indeed, by previous operational definitions of controllability, the two are indistinguishable since once an animal has learnt the actions that evoke a desired response then the increased likelihood of that response being effected (controllability as earlier defined) is entirely determined by the predictability of the action-response relationship.

A different kind of middle ground for controllability exists however. It may not be control *per se* that is enriching but rather the process of its acquisition. In natural habitats food and mates are not obtained by pulling levers. Since optimal solutions may change over time there is no reproductive advantage to be gained from enjoying control over one facet of the environment if one's competitors have already moved on to working out how to control another. Neophilia thus serves the clear function of motivating individuals to learn about their environment, to control their interactions with it, to be accurate predictors and to be ready to adapt to changing circumstances. From this perspective, enrichment may be best provided by objects that suggest controllability (thus evoking the neophilia response) but which actually resist control, thus maintaining the responsiveness.

Novelty, a quality that tends to elude definition (see Fragazy & Adams-Curtis 1991), can, from a cognitive perspective, be defined thus: a system retains novelty for an individual until the individual is satisfied that the means of controlling all properties in its range of interest

that can be controlled are discovered. Novelty is thus defined in terms of neophilia rather than vice versa. One outcome of this is that it becomes meaningless to object that any apparent enrichment found during the process of control acquisition is confounded with the effect of novelty, since novelty precisely *is* uncertainty regarding how an object's properties are to be controlled. A less desirable feature of this definition of novelty is that it is non-operational, resting as it does on the individual's perception of an object. Realistically however, this is inevitable since novelty is a perceptual quality, experienced subjectively, and not one which is necessarily tied to schedules of object exposure etc. Our purpose here is to provide a theoretical starting point for the provision of novelty.

The attractive qualities of novelty need not only reside in an animal's environment but can also exist within its own behavioural repertoire. Once control is acquired there will be no incentive to deviate from a single, optimal act. In contrast, during the process of learning to manage a novel object, novel behaviours must be produced in order to search for solutions to a new challenge. This is in no way a contrived manner of provoking behavioural flexibility in an animal. Behaviourism recognizes that the viability of operant conditioning rests on an innate tendency for animals to generate new behaviours spontaneously, from which rewarded ones are then selected (Plotkin 1994). Thus it is through the learning context that we have most hope of breaking stereotypes and encouraging a wider range of behaviour.

At present we have no direct evidence that the acquisition of control is more enriching than the repeated execution of acquired control. However, indirect evidence comes from the experiment of Hanson *et al* (1976) mentioned earlier. Monkeys able to control the onset of white noise showed lower cortisol levels than those that could not control the noise (where monkeys without control were the experimental 'control' group). However, when the facility to control the onset of noise was removed from the privileged monkeys, their cortisol levels rose to beyond that of the experimental controls. Since both the experimental controls and the control-deprived monkeys were experiencing the same absolute level of control (ie none), this could not have been the factor that determine welfare (as affects cortisol levels). Rather, it would appear that individuals monitor the control they enjoy relative to their expectations. Hanson *et al*'s experiment shows the damaging effects of a net decrease in control. We would predict a conversely beneficial effect of a net increase. This effect would decay once individuals' expectations of control rose to meet their ability for control.

Implications for novel object selection and animal welfare

We would like to finish with a slightly more practical perspective by considering novel objects themselves. We suggest that three aspects of controllability should be recognized. First, the *number* of controllable features and any interactions between them should be considered. The majority of enrichment toys are simple devices but some are better described as 'activity boxes' (eg Champoux *et al* 1990), affording multiple responses.

A second aspect of controllability is the *predictability* of the response, ranging from certainty to randomness. For example, 'puzzle feeders' can deliver food at the same time every day or at completely random times or in a semi-consistent fashion. Such predictability is a perfectly quantifiable property in information theory (see Shannon & Weaver 1949). The earlier discussion leads us to suspect that neither total predictability nor unpredictability would be stimulating. It is a well-known principle in behavioural psychology that variable

reinforcement schedules (ie those in which the relationship between behaviour and reward is variable) are more effective at eliciting operant responses than fixed reinforcement schedules. Nevertheless, frequency of action cannot be taken as a reliable indicator of enrichment. Variable reinforcement is also considered a prime determinant in some highly damaging forms of human behaviour, most notably gambling (Greene 1982).

Finally, we suggest that there exists a more qualitative *grade* of controllability for which we present a set of alternatives in Table 1. Previous enrichment attempts fall across the whole spectrum of these grades. Fixed enrichment devices cover the introduction of extra substrates on which animals can move or swing (eg Tripp 1985; McKenzie *et al* 1986). Moveable and malleable objects comprise the majority of enrichment toys. Analogue devices include the computer tracking games of Washburn and Rumbaugh (1992) where movements of a joystick produce corresponding movements of a cursor on a computer screen. Mirrors are also analogue devices. Examples of digital devices are the switch-operated control of white noise or radios, studied respectively by Hanson *et al* (1976) and Markowitz and Line (1989).

The grades in Table 1 are ordered in terms of increasing sophistication of cause and effect relationships, which effectively corresponds to the rarity of such relationships in natural habitats. Given its rather imprecise conception (see Novak & Drewson 1989) it is not entirely clear how enrichment is related to this dimension of grades, in which there is an inverse relationship between novelty and ecological validity. Certainly, if one's criterion of enrichment is the promotion of species-specific behaviours seen in the wild, then much analogue and all digital enrichment are ruled out. However, using such a criterion for enrichment is questionable for whilst it has a certain face validity, most notably in barren environments, and is laudably operational, it rather misses the point of enrichment, ie the promotion of well-being. Running for their lives from a predator is a species-specific behaviour that prey animals show in the wild and one unlikely to promote well-being.

Table 1 Grades of controllability in novel objects.

<i>Fixed</i>	Animal can move only with respect to object (eg swinging on bars)
<i>Moveable</i>	Animal and object free to move with respect to each other and enclosure (eg throwing or pushing objects, transfer between animals)
<i>Malleable</i>	Action applied to point on object results in effect at same location (eg squeezing rubber ball, bouncing on tree limbs)
<i>Analogue</i>	Action applied at one point generates analogue effect at another (eg use of levers)
<i>Digital</i>	No analogue relationship between cause and effect (eg most electronic mechanisms)

We propose these dimensions of controllability because they provide a unifying framework to compare enrichment devices and may reflect fundamental preferences of animals. Relatively few studies have identified the basic properties of their devices that promote enrichment, let alone test these effects comparatively. Chamove (1989) introduced a device that was deliberately designed to be unpredictable. This was a rope passing through to another enclosure where out-of-sight animals would swing on it making it appear to

spontaneously move around in the other enclosure. The rope occupied the chimpanzees much more than a predictable equivalent.

This is a relatively isolated example, however. We suggest that future experimental work should distinguish both between the effects of these dimensions of controllability and more generally between the relative contributions of complexity and controllability in enrichment. Identifying such properties is one effective way to formulate generalisable principles of enrichment that can be applied at the outset of possibly costly operations. It is our intuition that successes in enrichment to date can largely be attributed to the control rather than the complexity aspects of the stimuli that have been provided. Schapiro and Bloomsmith (1995) conducted a long-term enrichment study that explicitly examined the relative efficacy of three different types of enrichment: feeding, physical and sensory. Unlike the first two types, sensory enrichment, in which subjects could witness but not control (visually complex) video scenes, exerted no effect. Furthermore, in a preliminary experiment specifically designed to separate the effects of complexity and controllability we found that controllable objects were preferred over uncontrollable, but that visual complexity exerted no effect (Sambrook & Buchanan-Smith 1996).

Conclusions

We have attempted to show that the properties that make novel objects enriching can be analysed by recognizing the dimensions along which the objects vary, both in terms of complexity and controllability. Ultimately, we expect object preferences to be rooted in evolved strategies reflecting animals' behavioural ecology.

However, we do not wish to imply that the field of enrichment can be neatly tied up with a series of academic experiments. Each species is unique, but equally, so is each individual and, in behaviourally complex species, inter-individual variation and group dynamics are at least as likely to exert an effect on the success of the enrichment enterprise as any particular 'enrichment variable'. As such, experimental evidence should be biologically relevant and complemented by intuition and intimacy with the animals involved.

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