Control and Complexity in Novel Object Enrichment

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ABSTRACT

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 l 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 (e.g. 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 (e.g. 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, i.e. 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 (i.e. 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 (e.g. 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 (i.e. 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 (e.g. 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 stereotypies 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 enriched 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 nonoperational, 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 stereotypies 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 (i.e. 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' (e.g. 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 (i.e. those in which the relationship between behaviour and reward is variable) are more effective at eliciting responses than fixed reinforcemen schedules. Nevertheless, frequency of action cannot be taken as a reliable indicator o 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 (e.g. Tripp 1985; McKenzie et al 1986). Moveable and malleable objects comprise the majority of enrichment toys. Analogue device include the computer tracking games of Washburn and Rumbaugh (1992) where movement of a joystick produce corresponding movements of a cursor on a computer screen. Mirror are also analogue devices. Examples of digital devices are the switch-operated control a 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 nature, 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 a 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, i.e. 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.

Fixed	Animal can move only with respect to object (eg swinging on bars)
Moveable	Animal and object free to move with respect to each other and enclosure (eg throwing or pushing objects, transfer between animals)
Malleable	Action applied to point on object results in effect at same location (eg squeezing rubber ball, bouncing on tree limbs)
Analogue	Action applied at one point generates analogue effect at another (eg use of levers)
Digital	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 animals. Relatively few studies have identified the basic properties of their devices to 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 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, interindividual 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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REFERENCES

Adams B W, Adair E R, Olsen M C and Fritz M S 1992 Two squirrel monkey toys. *Laboratory Primate Newsletter 31(4)*: 11-12

Alferink L A, Crossman E K and Cheney C D 1973 Control of responding by a conditioned reinforcer in the presence of free food. *Animal Learning and Behaviour 1*: 38-40

Anderson J R and Chamove A S 1983 Allowing captive primates to forage. In: *Standards of Laboratory Animal Management* pp 253-256. Universities Federation for Animal Welfare: Potters Bar, UK

Bayne K A L, Dexter S L, Hurst J K, Strange G M and Hill E E 1993 Kong toys for laboratory primates: are they really an enrichment or just fomites? *Laboratory Animal Science 43*: 78-85

Biederman I 1987 Recognition by components: a theory of human image understanding. *Psychological Review 94*: 115-147

Bloomsmith M A, Finlay T W, Merhalski J J and Maple T L 1990 Rigid plastic balls as enrichment devices for captive chimpanzees. *Laboratory Animal Science 40*: 319-322

Box H O 1984 *Primate Behaviour and Social Ecology.* Chapman & Hall: London, UK

Box H O 1988 Behavioural responses to environmental change. Observations on captive marmosets and tamarins (*Callitrichidae*). *Animal Technology 39:* 9-16

Box H O 1991 *Primate Responses to Environmental Change*. Chapman & Hall: London, UK

Bryant C E, Rupniak N M J and Iverson S D 1988 Effects of different environmental enrichment devices on cage stereotypies and autoaggression in captive cynomolgous monkeys. *Journal of Medical Primatology 17*: 257-269

Butler R A 1954 Incentive conditions which influence visual exploration. *Journal of Experimental Psychology 48*: 19-23

Caine N G 1984 Visual scanning by tamarins: a description of the behaviour and tests of two derived hypotheses. *Folia Primatologica 43*: 59-67

Caine N G and Marra S L 1988 Vigilance and social organisation in two species of primates. *Animal Behaviour 34*: 208-220

Chaitin G J 1970 On the difficulty of computations. *Institute of Electrical and Electronics Engineers Transactions on Information Theory IT-16*: 5-9

Chamove A S 1983 Role or dominance in macaque response to novel objects. *Motivation and Emotion 7*: 213-228

Chamove A S 1989 Enrichment in chimpanzees: unpredictable ropes and tools. *Journal of the Association of British Wild Animal Keepers 16*: 139-141

Champoux M, DiGregorio G, Schneider M L and Suomi S J 1990 Inanimate environmental enrichment for group-housed rhesus macaque infants. *American Journal of Primatology 22*: 61-67

Chmiel D J and Noonan M 1996 Preference of laboratory rats for potentially enriching stimulus objects. *Laboratory Animals 30*: 97-101

Crook J H 1980 *The Evolution of Human Consciousness*. Clarendon Press: Oxford, UK

Csikszentmihalyi M 1975 *Beyond Boredom and Anxiety: The Experience of Play in Work and Games*. Jossey Bass: San Francisco, USA

Fragazy D M and Adams-Curtis L E 1991 Environmental challenges in groups of capuchins. In: Box H O (ed) *Primate Responses to Environmental Change* pp 239-264. Chapman & Hall: London, UK

Fragazy D M and Mason W A 1978 Response to novelty in *Saimiri* and *Callicebus*: influence of social context. *Primates 19*: 311-331

Glickman S E and Sroges R W 1966 Curiosity in zoo animals. *Behaviour 26*: 151-188

Greene J 1982 The gambling trap. *Psychology Today 16*(9): 50-55

Hanson J P, Larson M E and Snowdon C T 1976 The effects of control over high intensity noise on plasma cortisol levels in rhesus monkeys. *Behavioural Biology 16*: 333-340

Humphrey N K 1972 Interest and pleasure: two determinants of a monkey's visual preferences. *Perception 1:* 395-416

Inglis I R and Ferguson N J K 1986 Starlings search for food rather than eat freely available, identical food. *Animal Behaviour 34*: 614-617

Inglis I R, Forkman B and Lazarus J In press. Contrafreeloading working for food with free food present. A review, fuzzy model and functional analysis. *Animal Behaviour*

Jaenicke C and Ehrlich A 1982 Effects of animate vs inanimate stimuli on curiosity behavior in greater galago and slow loris. *Primates 23*: 95-104

Jolly A 1964 Prosimians' manipulation of simple object problems. *Animal Behaviour 12*: 560-570

Line S W, Clarke A S and Markowitz H 1989 Adult female rhesus macaque responses to novel objects. *Lab Animal 18(*4): 33-40

Line S W and Morgan K N 1991 The effects of two novel objects on the behaviour of singly caged adult rhesus macaques. *Laboratory Animal Science 41*: 365-369

Line S W, Morgan K N and Markowitz H 1991 Simple toys do not alter the behavior of aged rhesus monkeys. *Zoo Biology 10*: 473-484

Markowitz H and Line S W 1989 Primate research models and environmental enrichment. In: Segal E F (ed) *Housing, Care and Psychological Well-Being of Captive and Laboratory Primates* pp 203-212. Noyes Publications: New Jersey, USA

Markowitz H and Line S W 1991 The need for responsive environments. In: Rollin B E and Kesel M L (eds) *The Experimental Animal in Biomedical Research* pp 153-170. CRC Press: Boca Raton, USA

Marr D and Nishihara H K 1978 Representation and recognition of the spatial organisation of three dimensional shapes. *Proceedings of the Royal Society of London Series B 200*: 269-294

McGrew W C, Brennan J A and Russell J 1986 An artificial 'gum tree' for marmosets (Callithrix j. Jacchus). *Zoo Biology 5:* 45-50

McKenzie S M, Chamove A S and Feistner A T C 1986 Floor-coverings and hanging screens alter arboreal monkey behavior. *Zoo Biology 5*: 339-348

Menzel E W 1965 Responsiveness to objects in free-ranging Japanese monkeys. *Behaviour 26*: 130-150

Menzel E W 1978 Cognitive mapping in chimpanzees. In: Hulse S H, Fowler H and Honig W K (eds) *Cognitive Processes in Animal Behaviour* pp 96-109. Lawrence Erlbaum Associates: Hillsdale, USA

Menzel E W and Menzel C R 1979 Cognitive, developmental and social aspects of responsiveness to novel objects in a family group of marmosets (*Saguinus Juscicollis*). *Behaviour 70*: 251-279

Millar S K, Evans S and Charnove A S 1988 Older offspring contact novel objects soonest in callitrichid families. *Biology of Behaviour 13*: 82-96

Mineka S, Gunnar M and Champoux M 1986 Control and early socioemotional development: infant rhesus monkeys reared in controllable versus uncontrollable environments. *Child Development 57*: 12411256

Neuringer A J 1969 Animals respond for food in the presence of free food. *Science 166*: 399-401

Novak M A and Drewson K H 1989 Enriching the lives of captive primates: issues and problems. In: Segal E F (ed) *Housing, Care and Psychological Well-Being of Captive and Laboratory Primates* pp 161-182. Noyes Publications: New Jersey, USA

O'Neill P 1989 A room with a view for captive primates: issues, goals, research and related strategies. In: Segal E F (ed) *Housing, Care and Psychological Well-Being of Captive and Laboratory Primates* pp 135160. Noyes Publications: New Jersey, USA

Overmier J P, Patterson J and Wielkiewicz R M 1980 Environmental contingencies as sources of stress in animals. In: Levine S and Ursin H (eds) *Coping and Health* pp 1-38. Plenum Press: New York, USA

Parker C E 1974 The antecedents of man the manipulator. *Journal of Human Evolution 3*: 493-500

Piaget J 1959 *La naissance de L'intelligence chez Enfant, 3rd edition*. Delachaux et Niestle Neuchatel, Switzerland

Plotkin H C 1994. *The Nature of Knowledge*. Penguin: London, UK

Preutz J D and Bloomsmith M A 1992 Comparing two manipulable objects as enrichment for captive chimpanzees. *Animal Welfare 1:* 127-137

Sackett G P 1965 Manipulatory behavior in monkeys reared under different levels of early stimulu variation. *Perceptual and Motor Skills 20:* 985-988

Sackett G P 1966 Development of preference for differentially complex patterns by infant monkeys. *Psychonomic Science 6*: 441-442

Sambrook T D and Buchanan-Smith H M 1996 What makes novel objects enriching? A comparison of the qualities of control and complexity. *Laboratory Primate Newsletter 35*(4): 1-4

Sambrook T D and Whiten A 1997 On the nature of complexity in cognitive and behavioural science. *Theory and Psychology 7:* 191-213

Schapiro S J and Bloomsmith M A 1995 Behavioral effects of enrichment on singly-housed, yearling rhesus monkeys: an analysis including three enrichment conditions and a control group. *American Journal of Primatology 35*: 89-101

Segal E F (ed) 1989 *Housing, Care and Psychological Well-Being of Captive and Laboratory Primates*. Noyes Publications: New Jersey, USA

Seligman M E P 1975 *Helplessness: On Depression, Development and Death*. Freeman: San Francisco, USA

Shannon C E and Weaver W 1949 *The Mathematical Theory of Communication.* University of Illinois Press: Urbana, USA

Shefferly N, Fritz J and Howell S 1993 Toys as environmental enrichment for captive juvenile chimpanzees (*Pan troglodytes*). *Laboratory Primate Newsletter 32*(2): 7-9

Stolz S B and Lott D F 1964 Establishment in rats of a persistent response producing a net loss of reinforcement. *Journal of Comparative Physiology and Psychology 57*: 147-149

Tripp J K 1985 Increasing activity in captive orangutans. *Zoo Biology 4:* 225-234

Visalberghi E and Mason W A 1983 Determinants of problem-solving success in Saimiri and Callicebus. *Primates 24*: 385-396

Washburn D A and Rumbaugh D M 1992 Investigations of rhesus monkey video-task performance: evidence for enrichment. *Contemporary Topics 31*(5): 6-10

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