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FACTORS AFFECTING HUMAN SELF-CONTROL IN A LOCAL VERSUS GLOBAL CHOICE PARADIGM

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ABSTRACT

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FACTORS AFFECTING HUMAN SELF-CONTROL IN A LOCAL VERSUS GLOBAL CHOICE PARADIGM

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Recently, Rachlin (1995a) has criticised the traditional smaller-sooner vs. larger-later model of self-control on the grounds that it fails to capture many of the essential characteristics of the situations to which the everyday language sense of self-control is usually applied. Rachlin's alternative model sees self-control as choosing to act in ways that deliver relatively small immediate (local) rewards but that contribute to a larger overall (global) pattern of reward. The choice procedure of Herrnstein, Loewenstein, Prelec, and Vaughan (1993) offers a laboratory-based instantiation of these conditions. This thesis is concerned with the examination of factors that may affect human choice between local and global rewards.

The thesis reports four experiments that used the Herrnstein et al. (1993) paradigm to examined how cognitive and motivational factors may affect human choice. Overall, participants were found to be relatively insensitive to the global contingency. In Experiment 1, rewards were based on accumulating points. Participants preferred local reward when the difference in local rates was larger, but the provision of prospective and social comparative information reduced local choice. In Experiments 2 to 4, rewards were based on minimising delay. Experiment 2 manipulated the difference in local rates but the results were inconclusive. Experiment 3 found that global choice was increased by the provision of explicit delay information but that the rate at which the rewards changed between trials had no effect within the parameters studied. Experiment 4 found that the provision of a written description of the contingencies increased global choice relative to a control group but that a forced-choice training procedure did not. Generally, global strategies increased with awareness of the global contingency. Results are discussed in relation to Skinner's (1969) distinction between contingency-shaped and rule-governed behaviour.

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Chapter One - Theoretical Approaches to Self-control

1.1 Introduction

Self-control is important in western societies. People who are perceived to be weak willed and lack self-control are often harshly treated by society, particularly the media, as many politicians, football players and American Presidents would undoubtedly testify. However, commonplace versions of these high profile cases are not dissimilar to the many everyday problems attributed to lack of self-control that we all probably experience from time to time. There may be many instances each day when we may either act to gain an immediate reward or show self-control by postponing a gratification that conflicts with our longer-term interests. Many people probably face a choice of this kind every morning when they must decide whether to stay in bed or get up and going to work. However, although we probably all yield to temptation occasionally, for the majority of us the consequences are, thankfully, not serious enough to warrant the involvement of medical services, the judicial system, or even a front page headline.

It has been speculated that animals have evolved a predisposition to behave impulsively (see Logue, 1995b). Our ancestors would have faced problems in their environment that are similar to those encountered by wild animals in their natural habitats today (Kagel, Green & Caraco, 1986). Specifically, without agriculture and other modern technologies, food supplies and other future events would have been uncertain. In addition, the life expectancy of our ancestors would have been short compared to today's standards because even in periods of bountiful food our ancestors would have suffered poor nourishment and been more susceptible to accidents and disease. Under such conditions, it may have been evolutionarily adaptive to act for immediate gain as any detrimental long-term consequences of such behaviour were unlikely to be realised.

In the modern western world, at least, the majority of us no longer struggle for the basic necessities of life. Society has developed so that both food and shelter are easily available. The combined effects of good nutrition, shelter and advances in medical science mean we can expect to live well into what is considered old age. In 1991, life expectancy at birth for men and women was 73 and 79 years old respectively (Charlton & Murphy, 1997). So, whereas our ancestors spent most of their time dealing with mere survival, we have time to engage in many additional activities that our ancestors could never have contemplated.

Unfortunately, perhaps, we also have time for the delayed consequences of our behaviour to be realised. Thus, the predisposition to choose immediate rewards that was beneficial to our ancestors can now sometimes be maladaptive.

When extreme problems in self-control do occur the consequences can be severe. Theorists and practitioners perceive the lack of self-control as central to many challenging behaviours found in clinical and educational settings (Fisher & Mazur, 1997; Logue, 1986, 1995b), and in many social problems, such as criminality (Gottfredson & Hirschi, 1990; Wilson & Herrnstein, 1985), drug abuse and addiction (Heyman, 1996; Rachlin, 1997). Many practitioners regard the development of self-control as a more desirable goal for their clients than the simple alleviation of the palpable behavioural problem (Karoly & Kanfer, 1982). However, we all suffer from self-control problems to varying extents. We all have undesirable bad habits that, for some reason, we persist in doing despite the fact we wish to stop because they make us feel unhappy (Baum, 1994). Thus an understanding of self-control is relevant to us all.

1.1.1 Thesis Overview

One model, in which self-control is seen as the choice of a larger, but delayed reward (larger-later, or LL) reward over a smaller, more imminent reward (smaller-sooner, or SS), has dominated research into self-control for the last 25 years. Recently, however, Rachlin (1995a) has criticised this model on the grounds that it does not provide a perfect fit with many of our understandings of self-control in everyday life. To account for the weaknesses of the prevailing model, Rachlin has developed a novel theory that intuitively seems to better describe the conditions arising in self-control. A human choice procedure used by Herrnstein, Loewenstein, Prelec and Vaughan (1993) captures the characteristics of Rachlin's model, allowing its operation to be studied in the laboratory. The aim of this thesis was to examine the validity of Rachlin's new approach to self-control by using the choice procedure to investigate factors that may affect human behaviour.

The first two chapters of this thesis introduce the traditional model of self-control. Chapter 1 details the major theoretical approaches adopted by behaviour analysts trying to understand self-control while chapter 2 reviews the significant experimental literature and summaries the factors that have been shown to affect self-control behaviour in the laboratory. The shortcomings of the traditional model are then highlighted in chapter 3 and Rachlin's

(1995a) alternative approach to self-control is introduced. Chapter 4 describes the form and the characteristics of the choice procedure that provides the basis for the four experimental studies reported in chapters 5 through to 8. And finally, chapter 9 contains a general discussion of the experimental findings and discusses how Rachlin's model has furthered our understanding of self-control.

1.2 Defining Self-control

The behaviours that are commonly described in terms of self-control are many and varied. However, the fact that they are all perceived as involving self-control is an (implicit) acknowledgement that these situations are structurally similar. Researchers and theorists have long recognised that self-control does not involve the use of will power or any form of interpersonal conflict, but rather involves the factors affecting the control of behaviours that result in conflicting consequences at different points in time (e.g., Brigham, 1978; Mischel, 1966; Rachlin, 1974; Rotter, 1954, Skinner, 1953). The temporal dimension is essential because without it choice between two alternatives is simply a question of taste (Rachlin, 1980). To illustrate this point, consider a scenario where a person who prefers a fried breakfast to a bowl of cereal is given a free choice between these two alternatives. If the choice had no longer term implications for his or her weight and cardiovascular health then they would choose the fried breakfast because they preferred the taste; self-control would not be an issue. Only if the long term consequences are taken into account does it become relevant to discuss the choice in terms of self-control. Choosing the fried breakfast would, in this case, be impulsive while choosing the cereal would be self-control, because although the person prefers the fried breakfast the cereal has greater long term benefits.

Situations in which it is appropriate to talk about self-control have traditionally been conceptualised as involving mutually exclusive paths to rewards of different magnitudes occurring at different times (e.g., Logue, 1988; Rachlin, 1974). A schematic of a self-control situation is shown in Figure 1-1. Choosing a larger but more delayed reward (larger-later, or LL) over a smaller, more imminent reward (smaller-sooner, or SS) is interpreted as self-control; the alternative choice is impulsive (Ainslie, 1974; Rachlin & Green, 1972). Thus a pigeon choosing between a 1 s access to grain after 2 s and a 10 s access to grain after 6 s, or a child choosing between a single sweet now and a bag of sweets after ten minutes, or an adult choosing between lounging now and good cardiovascular health in later life have all been construed in terms of this model of self-control.

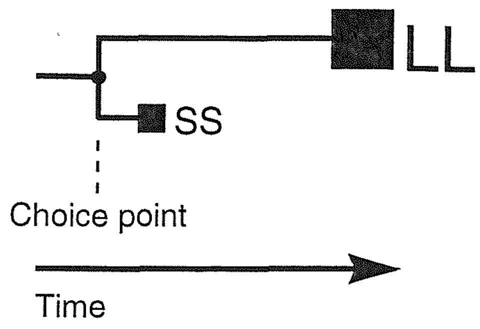

Figure 1-1. Schematic diagram of a self-control situation. At the choice point, choosing the larger-later reward (LL) over the smaller-sooner reward (SS) is interpreted as self-control; the alternative choice is impulsive.

Defining self-control in terms of a choice between SS and LL rewards is advantageous for several reasons. First, the definition is operational, allowing it to be used with ease in the design of experiments, that may use non-human as well as human participants. Also, as reward delay and magnitude are factors commonly manipulated in operant research, findings from other areas of research, such as the verbally-governed behaviour (e.g., Bentall & Lowe, 1987; Bentall, Lowe & Beasty, 1985) and behaviour under diminishing returns (e.g., Hackenburg & Axtell, 1993; Hackenburg & Joker, 1994), can extend our knowledge of self-control, and vice versa. In addition to operant research, the similarities between self-control problems and social dilemmas have also been noted and discussed extensively (e.g., Brown & Rachlin, 1999; Silverstein, Cross, Brown, & Rachlin, 1998). In a typical social dilemma task, two participants are separately given the choice between cooperating with each other and acting for their own self-interest (for reviews, see Dawes, 1980; Edney, 1980). Thus, there are four possible outcomes, and an example outcome matrix is shown in Figure 1-2. The largest outcome for each participant is if they choose self-interest while the other person chooses to cooperate. However, if both choose self-interest then both receive the worst outcome. The best option for both participants, and the one that produces the greatest average reward, results from both participants choosing to cooperate. To behave for the common good is, therefore, to show self-control and choose to cooperate rather than behaving impulsively and attempting to obtain the maximum personal reward at the expense of the other person and the risk that the other may also choose self-interest.

	Person 2	
Person 1	Cooperate	Self-interest
Cooperate	8 8	10 2
Self-interest	2 10	0 0

Figure 1-2. Example of a social dilemma outcome matrix.

Finally, and above all, outside the laboratory, the SS versus LL definition provides a convenient framework for characterising the arrangement of rewards in any situation perceived as involving a self-control conflict.

Although now widely adopted by researchers, the SS versus LL definition of self-control is not universally accepted and does not always seem to fit with how self-control has been viewed in the past. Notably, Skinner (1953) used the term self-control to describe situations in which the individual changes their own behaviour by altering the environmental antecedents. However, it seems that most disagreements are purely ones of terminology rather than representing radically different views of what actually constitutes self-control. For example, Mischel and colleagues refer to this type of choice situation in terms of *delay of gratification*, though this appears to simply be a synonym for self-control (e.g., Mischel, Shoda, & Rodriguez, 1989). Undoubtedly, some disagreements have arisen because some researchers have focused on the analysis of the situation, the particular arrangements of environmental contingencies that give rise to self-control, and others have concentrated on the mechanisms that allow self-control to occur.

Brigham (1978) and Baum (1994) have both proposed a slightly different analysis of the self-control situation, but both imply the SS versus LL model is an oversimplification of the contingencies that are involved in self-control. Brigham concluded that a self-control problem is a particular response that is either occurring or not occurring. For example, though both would be classed as instances of self-control, smoking and avoiding the dentist are structurally different. Smoking is a problem caused by a response occurring whereas not going to the dentist is a problem caused by a response not occurring. Overall, Brigham identified four distinct arrangements of consequences of responding and not responding that characterise self-control situations. These arrangements, examples of which are presented in Table 1-1, follow a common pattern: the specific situation depends on whether the consequences are reinforcing or aversive, but the immediate consequences are always relatively small compared to those that are delayed.

Table 1-1

Brigham's (1978) analysis of the consequences of responding (R_1) and not-responding (R_0) in self-control

		Consequences	
Response	Example	Immediate	Delayed
R_1		Minor reinforcing event	Major aversive event
R_0		No reinforcing event	No aversive event
Impulsive	Smoking	Nicotine & social reinforcers	Cancer, heart disease, etc.
Self-control	Not smoking	-	-
R_1		Minor reinforcing event	No reinforcing event
R_0		No reinforcing event	Major reinforcing event
Impulsive	Spending money	Less desired purchase	-
Self-control	Saving	-	Greatly desired purchase
R_1		Minor aversive event	No aversive event
R_0		No aversive event	Major aversive event
Self-control	Going to the dentist	Check-up	-
Impulsive	Not going to the dentist	-	Having cavities filled
R_1		Minor aversive event	Major reinforcing event
R_0		No aversive event	No reinforcing event
Self-control	Making new friends	Awkward social interaction	New friends
Impulsive	Not meeting new people	-	-

Baum's (1994) perspective differs from Brigham's (1978) by virtue of the fact that Baum emphasised that impulsive and self-control responses both produce immediate and delayed consequences, and that delayed consequences are always less certain than immediate ones. According to Baum, the distinction between the two types of responding is that choosing impulsively produces an immediate, small reinforcer and a delayed, large punisher while self-control produces an immediate, small punisher and a delayed, large reinforcer. For example, for a smoker, smoking provides the immediate reinforcement of nicotine but could lead to cancer and heart disease in later life. In contrast, not smoking results in immediate punishment by the withdraw symptoms but, in the long-term, results in better health. Baum termed the self-control situation a *contingency trap*, the conditions of which are summarised in Table 1-2. It is unclear whether Baum intended these conditions to be considered a general model characterising all self-control situations, but it would be difficult to accept as such because, with reference back to Brigham's analysis, it is hard to identify the consequences of not responding regardless of whether that response is considered self-control of impulsive.

Table 1-2

Baum's (1994) contingency trap

Response		Consequences	
		Immediate	Delayed
Impulsive		Small reinforcer	Large punisher
Self-control		Small punisher	Large reinforcer
	Example		
Impulsive	Smoking	Nicotine & social reinforcers	Cancer, heart disease, etc.
Self-control	Not smoking	Withdrawal symptoms	Health

Self-control has also been used to describe situations in which a person persists with a repetitive task while ignoring a distraction (Patterson & Mischel, 1975), inhibits or changes behaviour to confirm to social norms (Hetherington & Parke, 1993), and regulates emotional responses (Kokkonen & Pulkkinen, 1999). However, even these situations can be viewed as a choice between SS and LL rewards. Persisting in a repetitive task could be viewed as a choice between an immediately more interesting stimulus (SS) and the eventual reward of the repetitive task (LL). Inhibiting antisocial behaviour could be seen as a choice between some immediately rewarding rebellion (SS) and the long-term benefit of social approval (LL). And, controlling anger could be seen as a choice between the immediate satisfaction of lashing out at a provocateur (SS) and not being put on trial for assault (LL).

The fact that self-control involves a choice between a less preferred and a more preferred reward available at different points in time is indisputable. It is debatable, however, whether these conditions are best conceived as a simple binary choice between a SS reward and an LL reward, despite the fact that, as Logue (1988) has pointed out, most descriptions of either self-control or impulsiveness can usually be recast in such terms. It is possible that what the SS versus LL model really reflects is only the superficial characteristics of the self-control situation, and these may be different from the true contingencies of which behaviour is a function. Rachlin (1995a) has recently highlighted several ways in which the SS versus

LL model deviates from the everyday language use of the term self-control, and these criticisms are discussed in chapter 3.

Ultimately, the analysis of the circumstances in which people talk about self-control is only the first stage in explaining such behaviour, and says nothing of the mechanism or mechanisms that make it possible to defer gratification. Although its validity has been questioned, one model, the SS versus LL model, has successfully dominated research into the factors affecting self-control. In comparison, the actual mechanisms of self-control are more contentious, and several competing approaches have evolved.

1.3 Towards a Scientific Explanation of Self-control

1.3.1 Traditional and Lay Explanations

The foundations of many of our traditional and lay explanations of behaviour can be traced back to the teachings of the Church during the middle ages. The explanation of human behaviour advocated by the clergy was based on a dualistic perspective, in which a person was conceived as being composed of a corporeal body and a supernatural, insubstantial soul. Although the body and soul were seen as belonging to separate realms of existence, control of the physical body was wholly attributed to the soul. The next major step in the development of a scientific understanding of behaviour has been attributed to French philosopher and mathematician, René Descartes (1596-1650). Although Descartes also advocated a dualistic view, he is attributed with being the first to suggested that some movements of the body may be caused by mechanical means without the need for supernatural action. Descartes' ideas were probably based on his knowledge and observations of the mechanical figures that stood in the royal gardens at Versailles. These figures were made to move and produce sound through an ingenious hydraulic system that involved water activating limbs or operating machines that produced words or music. Some of these figures were operated by hidden pressure pads that were triggered by passers-by. Descartes reasoned that such a system may explain how external stimuli causes movement of the physical body in animals. According to Descartes, external stimuli excited nerves in the body that conducted that excitement to the brain. The brain then released a thin fluid — animal spirits — that travelled back down the nerve and caused muscles to contract and cause movement.

Despite developing a mechanistic explanation for some forms of behaviour, Descartes failed to completely separate his ideas from the prevailing theological viewpoint. Although he viewed non-human animals as biological machines that simply responded mechanically to external stimuli, Descartes maintained that humans possessed a soul that could ultimately override purely mechanically induced movements. He reasoned that the soul could also control behaviour by moving the pineal gland in the centre of the brain to release the animal spirits and cause movement.

Modern day lay explanations of self-control also tend to retain this dualistic way of thinking, though different names have evolved for the components involved in determining behaviour. Two types of explanations can be identified, though the boundaries between the two are vague and often aspects are blended into a unified theory. The first type of the explanation is based on the belief that self-control involves some form of intrapersonal conflict. The individual is conceived as host to two or more distinct centres of control, each of which guides behaviour according to its own set of principles. Situations that produce self-control conflict do so because the principles under which these centres of control operate advocate different courses of action. Commonly perceived adversaries in this conflict include mind versus body, reason versus passion, and cognition versus motivation. In each of the above cases, triumph of the former leads to self-control; the latter to impulsiveness.

The second part of the explanation, that often seems to be associated with a belief in intrapersonal conflict, assumes the existence of some form of specialised mental apparatus, usually referred to as either self-control or *will power.* Typically, when people invoke 'will power' to explain behaviour it is discussed as if it were a limited resource that a person physically possesses and they can choose to expend to counter impulsive responses. The term is generally discussed as if the resource were non-specific and thus applicable in any situations believed to require self-control, although, paradoxically, it is also sometimes accepted that a person may be unable to apply their will power to a particular source of temptation (i.e., when people say "He has no self-control when it comes to ...") .

Probably the most influential of these intrapersonal conflict theories, and certainly the most elaborate, was developed by Freud (1920/1955; 1923/1961). Freud imagined the psyche as being comprised of three distinct facets: the *id*, the *ego*, and the *superego*. These three systems have their own priorities but they interact to govern behaviour. The id is the primitive, bestial side of personality that generates the basic biological impulses and drives. It guides behaviour in accordance with the pleasure principle, that is a simple economic assessment of which course of action will lead to the greatest immediate pleasure regardless of later consequences. The ego, that develops during childhood, realises that immediate gratification is not always appropriate because it may be incompatible with the long-term well-being of the individual. It guides behaviour in accordance with the more moderate reality principle. Self-control problems occur when the course of action prescribed by the id conflicts with the ego's instinct for self-preservation. Much has been written on the intricacies of this power struggle, but such details are not immediately important to this discussion (for discussion, see Stevens, 1983).

Unfortunately, theories based on interpersonal conflict and more traditional beliefs about self-control have little explanatory power because they are not independently measurable. The supposed cause of a specific behaviour can only be determined after that behaviour has occurred, and so provides no means of predicting or controlling that behaviour as would be demanded from a truly scientific explanation. As Skinner (1953) pointed out, "It is of little help to tell a man to use his 'will power' or his 'self-control.' Such an exhortation may make self-control slightly more probable by establishing additional aversive consequences of failure of control, but does not help anyone understand the actual process" (p. 241) (cf. Baumeister & Heatherton, 1996). These sorts of pseudoscientific explanations, often called *mentalisms,* fail for two reasons: *superfluity* and *autonomy* (Baum, 1994; Skinner, 1974).

Mentalisms fail as explanations because they are superfluous. Their existence can only be determined from the behaviour they are supposed to explain. For example, if a person shows self-control it is because he or she has willpower, whereas if they are impulsive it is because willpower is lacking. As an explanation this is perfectly circular: Individuals must have willpower because of their behaviour and they behave as they do because of their willpower. Our understanding of why a person acted in a particular way, or how to modify that behaviour, is not advanced. Constructs such as willpower and self-control are fictional, invented to explain behaviour when there is no obvious external cause, and therefore they have no place in a scientific explanation.

Mentalisms are also commonly talked about as autonomous agents. An organism is autonomous if its behaviour is attributed to itself as opposed to an extrinsic agent. Animals are autonomous because they move under their own volition through the interaction between their nervous system and striated muscles. In comparison, a puppet is not autonomous in this way because, although it can move, its movement is determined by the puppeteer. Assigning autonomy to a whole organism is valid, but problems arise when autonomy is attributed to parts of an organism (Baum, 1994). In theories of intrapersonal conflict the competing entities are discussed as separate autonomous agents. If this were true then, like a puppet, any outward behaviour of the whole organism would merely be the result of the autonomous action of these controlling inner parts, and then they would be the rightful subject of psychological inquiry.

Ultimately, traditional explanations do little to further our understanding of behaviour. Tales of intrapersonal conflict and willpower are merely fictional constructs that provide a plausible commentary on behaviour, but in truth explain nothing, and could be considered detrimental because they obscure and distract from true scientific inquiry. Despite these criticisms, the terminology of self-control (e.g., impulsiveness, will power etc.) may still be useful as a shorthand for describing the patterns of behaviour that occur in situations of intertemporal conflict (Rachlin, 1980). If we are to explain this behaviour, however, we must look beyond traditional explanations to develop a scientific understanding of the factors that determine behaviour.

1.3.2 Behavioural and Cognitive Approaches

Psychology is commonly perceived as the study of mind and behaviour. However, what this actually means is a matter of great debate. The twentieth century saw the growth and development of two distinct approaches to psychology: behaviourism and cognitivism. Many disputes between proponents of these two schools involved ways of talking about behaviour rather than actual research findings (Catania, 1992; Rachlin, Logue, Gibbon, & Frankel, 1986). After all, whatever phenomenon is subjected to psychological inquiry, theories must be formed exclusively from behaviour because only what an organism does is directly observable. A great deal of this observation is undertaken in the laboratory where the factors affecting behaviour can be strictly controlled. It is, however, well documented that human performance in the laboratory is different from that of other animals in simple conditioning tasks (see Lowe, 1979, for review). These differences are typically ascribed to humans' unique capacity for verbal behaviour and their tendency to follow rules (Hayes, 1989). Language also allows people to describe their thoughts and feelings, and such reports are commonly believed to provide privileged information about the individual. However, it is a fallacy that such descriptions necessarily allow an insight into the factors controlling a person's actions; verbal descriptions are merely another form of observable behaviour (Skinner, 1953). Despite sharing a reliance on observable behaviour for data, important philosophical differences exist between behavioural and cognitive approaches (see Hayes, Hayes & Reese, 1988, for discussion). The main points of contention lie in a fundamental disagreement in the perceived purpose of science and the importance placed on inner states and higher mental processes that are not directly observable and so their existence can only be inferred.

The primary purpose of science from a behaviour analytic viewpoint is prediction and control (Skinner, 1953). Prediction and control are the central criteria for judging the worth of an explanation (Hayes & Brownstein, 1986). An event or factor can only be part of a causal explanation of a behaviour if it can be manipulated and thus used in its prediction and control (Skinner, 1953). The behaviour analysts' objection to inner states and higher mental processes, therefore, is not that they do not exist but that, because they cannot be manipulated, they are not relevant to a functional analysis of behaviour (cf. Rachlin, 1992; Skinner, 1974). The behaviour analytic view is perhaps best summarised by Skinner (1953): "We cannot account for the behavior of any system while staying wholly inside it; eventually we must turn to forces operating upon the organism from without" (p. 35).

In comparison, cognitivists maintain that the purpose of science should be understanding rather than control (Millward, 1984). Behavioural explanations are incomplete because they do not explain how organisms are capable of behaving (Marshall, 1984). Although directly unobservable, the processes that occur within the brain can be inferred from behavioural data, and are necessary if we are to develop a complete understanding of human behaviour. Typically, cognitivists treated the brain as an information-processing system, like a computer, and their ultimate goal is to produce a model to explain how changes in the environment correlate with changes in behaviour (e.g., Carver & Scheier, 1982; Metcalfe & Mischel, 1999)

Cognitive scientists typically consider behavioural explanations to be vague and incomplete, while behaviour analysts consider the models and theories of the cognitivists to be an unnecessary waste of time (Hayes, Hayes & Reese, 1988). Without denying the validity of any cognitive models of self-control, this thesis takes a behavioural stance. Thus, the kind of explanation of self-control that will be adopted here is one that focuses on the external factors that determine behaviour rather than attempting to reveal any potential internal mechanisms.

1.4 Behavioural Approaches to Self-control

1.4.1 Self-control: One Behaviour Controlling Another

One of the earliest behavioural accounts of self-control was put forward by Skinner (1953). Skinner observed that when a person controls their own behaviour, "He controls himself precisely as he would control the behavior of anyone else—through the manipulation of variables of which behavior is a function" (p. 228). For example, to control a person's behaviour you could (1) physically prevent him or her from responding (e.g., incarceration), (2) make a punishment contingent on responding (e.g., a monetary fine), or (3) use distraction so that the cues that signal that a response will be rewarded are missed. When it comes to controlling their own behaviour people employ similar techniques. People with a severe overeating problem may choose to have an operation that decreases the amount that they can physically eat (e.g., the jaw may be closed by implanting wires or the volume of the stomach may be surgically reduced). Alcoholics may voluntarily take the drug Antabuse, that causes a catalogue of unpleasant symptoms if alcohol is subsequently consumed. And students may chose to study in the library where there is less chance of friends causing a distraction from work.

From this analysis, Skinner (1953) drew the distinction between the *controlled response* and the *controlling response*. In a self-control situation, the controlled response is undesirable because of the aversive, or loss of the positive, long-term consequences, but it is maintained because of the more immediate reinforcers it produces. This analysis fits favourably with those discussed above, in section 1.2. The controlling response is any behaviour that reduces the probability of the controlled response occurring, and is, according to Skinner, "automatically" reinforced by the reduction of the delayed, aversive consequences of the controlled response. For example, drinking alcohol (a controlled response) is reinforced by the relatively immediate psychophysiological effects and the associated social reinforcers, but may also result in negative consequences brought about by the subsequent lack of inhibition and the risk of hangover in the morning. Avoiding these negative consequences could be achieved in several different ways (the controlling responses), such as only entering a bar after last orders or deliberately only carrying enough money to purchase one drink. Skinner's main argument was that these controlling responses are themselves operants, under the control of external contingencies of reinforcement. Although a few may be naturally occurring, generally these contingencies are arranged by the social community and form the basis of the society's ethical and moral codes (Skinner, 1969). It was Skinner's contention that if society is responsible for arranging the consequences that ensure self-control, then little responsibility actually resides with the individual.

The idea of one behaviour controlling another is an important one that has persisted in behavioural theories of self-control, although Skinner's (1953) terminology has been replaced, perhaps to make it more acceptable to cognitive psychologists. Controlling responses are usually referred to as *commitment strategies*, because they commit the person to choosing the self-control option (Rachlin & Green, 1972). However, Skinner also claimed that, amongst other factors, operant conditioning depended on immediacy of reinforcement. In some case, it is difficult to identify what is immediately reinforcing a commitment strategy when the apparent consequences of such a response may be greatly delayed. So, why does commitment work?

1.4.2 Temporal Discounting of Future Rewards

It is generally accepted within the behavioural-economic literature that humans and other animals discount the value of future rewards (see Loewenstein & Elster, 1992). Such discounting implies an automatic reduction in the subjective value of a reward as a function of the delay until its delivery. In other words, the longer you must wait for a reward the less that reward is worth to you now. Most people could vouch for this phenomenon from personal experience, but there is also considerable empirical evidence to support it (see Ainslie & Haslam, 1992; Ainslie & Herrnstein, 1981; Herrnstein, 1981; Kacelnik, 1997, for reviews).

A key feature, that any proposed model of discounting must account for, is the fact that failures of self-control are often marked by a preference reversal, a lack of correspondence between what one initially says and how one eventually behaves (e.g., sincerely saying you have given up smoking and then later having another cigarette). Preference reversal will only occur if the discount functions of the two alternative rewards intersect: thus an imminent, and previously less valued reward becomes more valuable than a delayed but larger reward as the time to both decreases by the same amount. Figure 1-3 shows a self-control choice between two rewards, one SS available at T_2 and one LL available at T_3. The curved functions subtended to the left show the hypothetical discounted values of the rewards as the delay to their delivery increases. At T_1, the discounted value of the LL reward is greater than that of the SS reward. However, as the SS reward becomes increasingly imminent, the functions converge until they intersect at T_x, after which the SS reward is the more valued of the two alternatives. The point of intersect is often referred to as the indifference or ambivalence point because there is no preference for either of the two rewards.

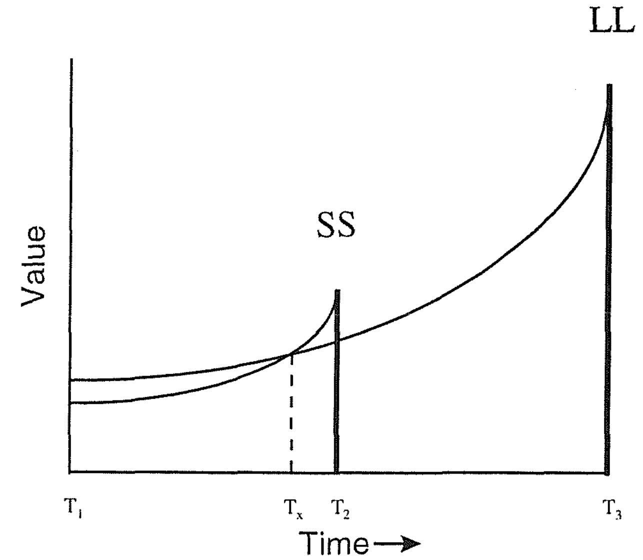

Figure 1-3. Illustration of a self-control choice, a smaller-sooner reward available at T_2 and a larger-later reward available at T_3. The curved functions subtended to the left show the discounted value of the rewards as the delay to their delivery increases. At T_1 the discounted value of the LL reward is greater than that of the SS reward. As the SS reward becomes increasing imminent the functions converge until they cross-over, at T_x, and the SS reward becomes the more valued of the two alternatives.

The exact quantitative form of discount functions has been a subject of much research and debate. In economics, discounting has traditionally been modelled by exponential functions (Ainslie, 1975; 1992). However, it seems unlikely that animals discount exponentially. Exponential functions decline by a constant proportion of the amount remaining per unit time, and so it impossible for two functions declining at the same rate to intersect and produce the preference reversal effect. For the discounted value of two rewards to intersect the function must decline steeply over short delays and then level out into a gradually decreasing tail. Recent behavioural research seems to have identified a universal discounting function, called the *matching law*, that has such a form (see Herrnstein, 1997, for review).

The matching law has developed from the empirical findings of Richard Herrnstein. Herrnstein (1961) studied the way that pigeons behave on concurrent schedules of reinforcement and discovered that the rate of responding on a schedule was proportional to the rate of reinforcement on that schedule relative to other concurrently available alternatives. For example, a pigeon will peck a key associated with a variable-interval 30 s (VI 30) schedule twice as often as a key associated with a VI 60 schedule when both schedules are simultaneously available.

The matching law is relevant to self-control because it provides a quantitative prediction of choice between two alternatives, based solely on external factors: reward rate, magnitude and delay. The matching law predicts that a reward's value will decrease hyperbolically as the delay to its delivery increases (cf. Myerson & Green, 1995). A property of two opposed hyperbolic functions is that they have the potential to intersect, which is necessary if preference reversal is to occur.

Although, considerable research has been devoted to understanding behaviour in delayed reinforcement paradigms, and the specific quantitative form of the matching law has been refined over years, it has always retained its hyperbolic nature (e.g., Ainslie, 1974; Baum & Rachlin, 1969; Bradshaw & Szabadi, 1992; Green & Synderman, 1980; Herrnstein, 1981; Logue, 1988; Mazur, 1987; Mazur & Herrnstein, 1988; Rachlin & Green, 1972; Vaughan, 1985). For example, a recent model of self-control derived from the matching law is the "hyperbolic response strength" model, proposed by Mazur and Herrnstein (Mazur, 1987; Mazur & Herrnstein, 1988). Mazur (1987) recorded pigeons' responses to delayed rewards of various magnitude and found that the data was best described by the hyperbolic function shown in Equation 1-1.

$$V_d = \frac{V}{(1 + kD)} \qquad (1\text{-}1)$$

Equation 1-1 shows the discounted value of a reward (V_d) as a function of its prediscounted value (V) and the delay until its delivery (D). The parameter k represents the degree of discounting, and varies to account for individual differences between subjects and procedural difference between experiments. In a self-control paradigm, where SS and LL rewards are opposed, the matching law predicts that indifference between the two choices will occur when the discounted values of both choices are equal (i.e., $V_{d(SS)} = V_{d(LL)}$).

Consider a self-control choice between a SS and LL rewards, as shown in Figure 1-3 ($V_{LL} > V_{SS}$; $D_{LL} > D_{SS}$). Under certain delay conditions $V_{d(SS)}$ will be greater than $V_{d(LL)}$, and consequently behaviour will be impulsive. For example, Equation 1-2 shows a situation where a SS reward of value 2 delayed by 1 s, has a greater discounted value than an LL reward of value 6 delayed by 9 s. For reasons of simplicity, *k* equals 1 in both Equation 1-2 and Equation 1-3 and hence is omitted.

$$V_{d(SS)} = \frac{2}{(1+1)} = \mathbf{1} > V_{d(LL)} = \frac{6}{(1+9)} = \mathbf{\frac{3}{5}} \qquad (1\text{-}2)$$

If a constant delay is added to both the SS and LL rewards, there will come a point as the delays increases when $V_{d(LL)}$ will become greater than $V_{d(SS)}$ and preference will reverse. For example, if the delays to both of the above SS and LL rewards are increased by 6 s, then the discounted value of the LL reward will be greater than that of the SS reward, as shown in Equation 1-3.

$$V_{d(SS)} = \frac{2}{(1+7)} = \mathbf{\frac{2}{8}} < V_{d(LL)} = \frac{6}{(1+15)} = \mathbf{\frac{3}{8}} \qquad (1\text{-}3)$$

A key implication of a stable set of hyperbolic discount functions is that under certain conditions of differential delay it is theoretically impossible to obtain the LL reward (i.e., to show self-control) because at the time the SS reward becomes available its subjective value is greater than the alternative (see Figure 1-3). How then is it possible to show self-control?

1.4.3 Self-control through Commitment

The generally accepted explanation of the ability to resist choosing the SS reward is that, before the discounted values of the two alternatives intersect, the individual may employ some form of *commitment strategy*, that places a constraint on the opportunity to choose the SS reward (Rachlin & Green, 1972). The similarities between the idea of achieving self-control through the use of a commitment strategy and Skinner's (1953) notion of the controlled and the controlling response have already been noted in section 1.4.1. In terms of Figure 1-3, before T_x when the discounted value of SS will exceed LL, the individual emits a controlling response so that by T_2 the SS reward is either devalued, or the opportunity to choose is removed.

Physical restraint, the actual prevention of access to the SS reward, is a powerful form of commitment. Such commitment can be seen when alcoholics or drug addicts voluntarily enter a clinic that will physically prevent them access to drink and drugs, or when individuals with severe weight problems have their jaws wired together or their stomachs stapled to physically decrease the amount that they can eat. Analogous behaviour can also be produced in the laboratory. In two seminal papers, Rachlin and Green (1972) and Ainslie (1974) showed that pigeons could learn to achieve self-control by using a physical restraint strategy. In these studies, that will be discussed in detail in chapter 2, the birds experienced a series of forced-choice and free-choice trials, illustrated in Figure 1-4 as pathways A and B. One kind of forced-choice trial allowed only a response that led to the SS versus LL choice a few seconds later (pathway A); the other kind of forced-choice trial allowed only a response that required the birds to experience the effects of not being able to choose later, instead being forced to wait for the LL reward (pathway B). In the test phase, when the birds had a free-choice between the two reward pathways, provided that the interval between the first and second choice points was sufficiently long, the birds preferred pathway B that denied them the later choice and ensured that they received the LL reward. However, although physical restraint is a powerful form of commitment, it is potentially the most disruptive to a normal life. Also, unlike the predictable, experimenter controlled consequences that exist in the laboratory, in real life physical restraints can often be circumvented. An alcoholic, for example, could simply leave a clinic or arrange to have alcohol smuggled in. Also, once the physical restraint is removed, the problematic behaviour is likely to re-occur.

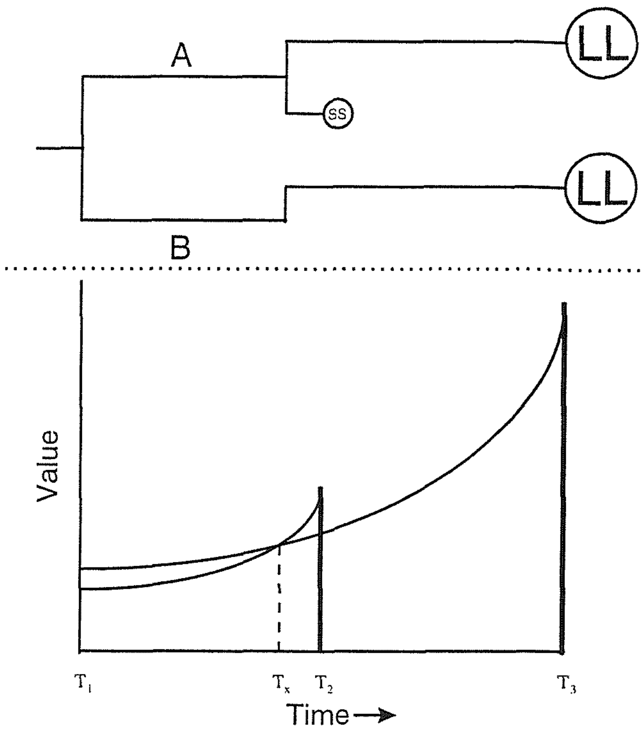

Figure 1-4. Illustration of commitment through physical restraint, as studied by Rachlin and Green (1972), above a diagram showing the discount functions of a SS reward and an LL reward. Between T_1 and T_x the choice may be made to progress via either the upper of lower paths. The upper path leads to the standard SS versus LL self-control choice occurring at T_2. However, at T_2 on the lower path, the SS reward is unavailable and the participant must wait for the LL alternative at T_3.

Rather than physical restraint, many everyday commitment strategies involve punishment that is contingent on the impulsive behaviour. Schelling (1992) reported the example of a drug clinic that, as part of their treatment programme, required their clients to write a letter confessing their drug dependency. It was threatened that if clients later tested positive for drugs, their letter would be send to either their employer or to the authorities (presumably ruining their lives). Such extreme measures may be very successful at controlling behaviour, but in everyday life the penalties of yielding to temptation are usually less severe and less certain.

Self-control from commitment strategies involving restraint and punishment are undeniably powerful methods of controlling behaviour. However, in everyday life, self-control usually occurs without the use of such explicit devices. Many people who eat moderately have no obvious constraints that prevent them from being exposed to SS rewards: Sensible eaters simply eat moderately despite frequent encounters with the dessert trolley. Similar observations may be made concerning most situations in which people perceive temptation. In these situations it often appears that behaviour is controlled by the delayed rewards resulting from self-control. However, as Skinner (1953) has noted, psychologists have been reluctant to ascribe causality to temporally distant events, preferring instead to take a cognitivist approach and bring those events forward to the present by placing them within the organism (cf. Carver & Scheier, 1982; Skinner, 1977). Given the observation that older people are generally perceived to be more successful at self-control without the need of external commitment strategies, the basic premise is that external commitment strategies are internalised over time. For example, Frank (1992) has claimed that the function of negative emotions is to act as internal tools for self-control. However, internalise commitment is not necessary to explain self-control in the absence of an observable commitment strategy.

1.4.4 Coping with Non-Direct Acting Contingencies

The principle of reinforcement states that behaviour will be strengthened if followed by positive consequences, and historically, at least, it was believed that the time between response and reinforcer had to be very short, if not immediate, for reinforcement to occur (see Williams, 1983, for discussion). However, this has posed behavioural analysts with a problem because the behavioural consequences of self-control seem to occur some considerable time after their causal response. Such contingencies have been termed *non-direct acting* (Malott, 1989). The question is, can non-direct acting contingencies cause behaviour?

Whether principles of learning derived from the performance of non-humans can be applied directly to human behaviour has been widely debated. For example, whereas the performance of non-humans on fixed-interval schedules is orderly and predictable, human behaviour is more varied. The classic scalloping pattern of responses found with animals is supplanted in adult humans with either a pattern of high- or low-rate responding (see Lowe, 1979, for review). Some researchers have attributed these findings to the ability of verbal rules to govern behaviour (Baum, 1994; Hayes, Zettle, & Rosenfarb, 1989; Lowe, 1979).

Much has been written on the intricacies of rule-governed behaviour (see Hayes, 1989). A rule is generally defined as verbal discriminative stimulus that signals that a certain behaviour may result in a certain consequence (Skinner, 1969). For example, warning someone not to touch a hot object describes the contingency where a touching response will be punished by pain. People may be inclined to follow rules because of a long personal history in which following rules has been reinforced. As a result, rule-following becomes a generalised response (Zettle & Hayes, 1982).

Many researchers assume that response and outcome must be temporally contiguous if reinforcement is to occur (Williams, 1983). Based on this belief, proponents of rule-governed behaviour argue that LL rewards do not function as causes of behaviour because the consequence of the response are temporally distant, although as Malott (1989) has pointed out, "... with the right rules and the right conditions, a delayed outcome does appear to control behaviour almost as if it were direct-acting, behaviorally effective consequence reinforcing or punishing that behavior" (p. 275). So, if a person behaves so as to obtain a LL reward in preference to a SS rewards, it is because they are following a rule ("avoid the SS reward"), not because the delayed outcome reinforces that behaviour. Once the LL reward has been obtained, it is feasible that there may be a transition from control by the rule to control by the delayed consequence, but not necessarily.

1.5 Summary

Self-control has been defined operationally as the choice of a larger, but more delayed reward over a smaller, but more imminent reward; the alternative choice is impulsive (Ainslie, 1974; Rachlin & Green, 1972). Situations where opposed rewards are arranged in this format occur frequently in everyday life, and are regularly identified by practitioners as causing behavioural problems in clinical and education settings (Fisher & Mazur, 1997; Logue, 1995b).

Traditional and lay explanations of self-control tend to involve intrapersonal conflict between two opposing centres of control within the individual. Unfortunately, such explanations are spurious because the supposed cause of behaviour can only be determined after the behaviour has occurred, and thus offer no means to predict or control that behaviour.

Current behavioural theories suggest that behaving impulsively is the result of organisms discounting the value of future rewards. Such discounting implies an automatic reduction in the subjective value of a reward as a function of the delay until its delivery (see Loewenstein & Elster, 1992). Given stable discount functions it is theoretically impossible to show self-control, to chose the LL reward over the SS reward in a free choice situation. However, when there is a long delay preceding both rewards, organisms may demonstrate self-control by employing a commitment strategy, that places a constraint on the opportunity to choose the SS reward (i.e., Rachlin & Green, 1972). However, explanations of self-control that occurs without any observable commitment strategy remain controversial.

Chapter Two - Review of Experimental Literature

2.1 Introduction

This chapter is a review of a cross-section of the experimental literature that has explored self-control behaviour under the traditional SS versus LL model. Perhaps one of the reasons that this model has been so successful is that it is operational, allowing it to be used easily in the design of experiments. The aim of this review is to highlight the methodologies that have been employed by those researchers exploring the factors controlling self-control, and to examine the empirical evidence that supports and contradicts temporal discounting as an explanation of impulsiveness behaviour (see Ainslie & Haslam, 1992). Several distinct approaches to self-control can be identified. Probably the most famous is the *delay of gratification* paradigm developed by Walter Mischel and colleagues (see Mischel, Shoda, & Rodriguez, 1989, for review), and these studies will be considered first. Although these delay of gratification studies do not address temporal discounting as an explanation, they are important because they highlight the role of the development of language in self-control. Following these studies, the research that has adopted an operant approach to the problems of self-control will be discussed. Finally, the chapter concludes with a summary of the factors that have been identified as determinants of self-control.

2.2. Delay of Gratification: Mischel's Social Learning Paradigm

2.2.1 Human Studies

As mentioned above, the approach to self-control developed by Mischel and colleagues is probably perceived my many as the archetypal design of self-control experiments. The approach is based on the underlying belief that self-control is mediated by internal cognitive and attentional processes (see Metcalfe & Mischel, 1999; Mischel et al., 1989 for reviews). In general, these studies take a developmental perspective, and focus on how children develop the ability to wait for delayed rewards.

In one of the earliest studies, Bandura and Mischel (1965) investigated the effect that modelling had on the self-control behaviour of 8- and 9-year-old children. Initially, the children were asked to express a preference for the SS or LL reward in a series of hypothetical self-control choices. These choices involved either small amounts of money (e.g., 25 cents today or 35 cents in one week) or involved different quantities of sweets or toys (e.g., a bag of peanuts today or a can of mixed nuts in two weeks). From their responses the children were either classified as *low-delay*, meaning they generally chose the immediate reward, or *high-delay*, meaning they generally chose the delayed reward. The children in each of these groups were then exposed to one of three treatments conditions. In the first treatment condition, the children watched the experimenter ask an adult (confederate) to express a verbal preference for either the SS or the LL reward in a series of hypothetical self-control choices. For the low-delay children the adult consistently chose the delayed reward and made pre-scripted comments about the benefits of waiting for such rewards. For the high-delay children the adult consistently chose the immediate reward and made pre-scripted comments about the benefits of taking what is immediately available. In the second treatment condition, the children did not physically observe an adult, but instead were told by the experimenter what choices an adult had made when asked earlier. As in the first treatment condition, the low-delay children were told the adult chose the delayed reward and the high-delay children were told that the adult chose the immediate rewards. In the third treatment condition, the control condition, the experimenter just described the choices and did not given any information regarding preference.

Several weeks after the initial phase, the children were again tested for their preference for SS and LL reward with hypothetical choice situations similar to those they had previously experienced in the initial assessment exercise. The children were motivated to respond honestly by the knowledge that they would receive one of their preferred rewards. The results of this study showed that, regardless of whether the children observed a live adult or were told how an adult had chosen, the groups initially rated as low-delay and high-delay both displayed a shift in preference towards the behaviour modelled in the treatment condition. In other words, the children rated as impulsive became more self-controlled and those rated as self-controlled became more impulsive. These findings indicate that, for children at least, the behaviour of others can influence behaviour in self-control situations, and may override any preference they may have based purely on the delay and magnitude of the reward.

Mischel's later work focused of the what children do while waiting for a delayed reward, and how their behaviour relates to how long they are prepared to wait for a reward (see Mischel et al., 1989). These *delay of gratification* studies abandoned hypothetical situations, and instead required the child to make one actual self-control choice between a SS and an LL reward. In general, the experimental session began with the child being asked to express a preference between two rewards, for example, whether they would prefer a biscuit or a pretzel. The child was then told that the experimenter would leave the room and they must wait for their return before they would receive their preferred reward. However, they were also told that they could terminate the waiting period at any time by some prearranged signal, such as ringing a bell for example, but if they did so they would receive the less preferred reward instead. During the delay period, the participant's behaviour was covertly observed through a one-way mirror. Within this paradigm, the experimental manipulations usually involved either altering the task instructions or the stimuli present during the choice interval. For example, Mischel and Ebbesen (1970) questioned whether the actual physical presence of reward was a factor in how long a child will wait for a more preferred, but delayed reward. In their study, that follows the basic procedural outline described above, one group of children had the food alternatives left on the table in the room during the delay period and another group did not. They found that children waited longer before terminating the delay period when neither reward was physically present, 11 minutes on average, compared to an average of 1 min when the both the rewards were present. To determine whether this effect was purely the result of attending to the rewards Mischel, Ebbesen, and Zeiss (1972) conducted a series of experiments with and without rewards present but in addition the children were given tasks to distract their attention from the food. One group of children were given a toy to play with and another group were simply instructed to think about 'fun things'. Both of these distracter tasks resulted in the children waiting longer before they terminated the waiting period. Without a distracter task the average waiting time was less than 60 s, but the waiting times with the toy and the "think" instruction were on average 8 and 12 minutes respectively.

Mischel et al. (1989) has interpreted the findings from the studies using the delay of gratification paradigm, only two of which are described briefly above, as evidence that the deployment of attentional processes is crucial in self-control. Rodriguez, Mischel and Shoda (1989) observed children of different ages in a delay of gratification experiment and recorded the percentage of time they spent attending to the rewards, the bell (the ringing of which ended the delay period) and to other stimuli into the experimental room. They found that the younger the children the more likely they were to spontaneously attend to the reward, and that attending to the reward resulted in the children waiting for only a short period of time before terminating the delay period. The finding that self-control increases with age is, Mischel et al. suggest, evidence that the ability to delay gratification is linked with the development of language skills (cf. Logue, Forzano, & Ackerman, 1996) and of attentional strategies. However, if the ability to delay gratification is dependent on the development of language, then it must be predicted that non-humans would always behave impulsively under analogous conditions.

2.2.2 Comparative Studies

After examining the delay of gratification studies, Grosch and Neuringer (1981) questioned whether pigeons might not show similar behaviour to that shown by children under analogous conditions. To this end, they conducted a series of experiments, the two that relate directly to the studies of Mischel and Ebbesen (1970) and Mischel, Ebbesen and Zeiss (1972) will be described here.

The basic apparatus used by Grosch and Neuringer (1981) was an operant conditioning chamber that contained a response key, that could be lit with a red light, above two hoppers with clear Plexiglas doors. Two types of grain (mixed racing grain and Kasha grain) could be delivered by the different hoppers and each was lit when active, one blue and one green. Pigeons are known to prefer mixed racing grain to Kasha grain, but readily eat Kasha grain when it is the only food available. In the basic procedure, pigeons, maintained at 80% of their free-feeding weight, were given a choice between waiting between 15 and 20 s for a 3 s access to racing grain but they could peck the red-lit response key at any time and receive an immediate 1.5 s access to Kasha gain. In the pilot study and training session it was established that the birds —as predicted by temporal discounting— generally waited for the LL reward when the prereinforcement delay was 5 s but pecked and received the SS reward when the prereinforcement delay was 15 s. Following either reward there was a 20 s postreinforcement delay during which the experimental chamber was unlit. Each bird typically experienced 30 trials in a session.

Mischel and Ebbesen (1970) found that children were more impulsive when they could see both rewards. Grosch and Neuringer's (1981) equivalent study, adopted an ABA design. During Phase A both hoppers were lit and active throughout the prereinforcement period so that the rewards were visible to the pigeons. To obtain reward the birds either had to peck the response key, and thus receive the SS reward, or they had to wait until the LL reward became available. When food was available a tone sounded continuously and the response key was darkened. If the pigeon tried simply to obtain grain without pecking or waiting, the hoppers were deactivated and there followed a 20 s blackout before the next trial began. Conditions during Phase B were identical to the Phase A except that the hoppers were not active during the prereinforcement period, so the pigeons could not view the rewards. The duration of the wait period alternated between 5 and 15 s on each trial. Each session consisted of 30 trials and each phase of the experiment last for 10 to 20 session, or until the bird's behaviour become stable.

Of the four birds who started the experiment, two were dropped, one because it kept trying to obtain food without pecking or waiting and one because although it pecked the response key it would not eat the less preferred grain. The behaviour of the two pigeons who completed the experiment can however be seen as similar to the behaviour of the children in Mischel and Ebbesen's (1970) study. Taking just the final three sessions of each phase, when the food was present (Phase B) the birds waited for the LL reward on 6.6% of the trials and when the food was not present (Phase A) the birds wait for the LL reward on 83.5% of trials.

Mischel, Ebbesen and Zeiss (1972) found that children were less impulsive when given the opportunity to play with a toy during the wait period. To produce equivalent conditions, Grosch and Neuringer (1981) added a second response key, that was lit orange when active, and hopper to the rear wall of the conditioning chamber, opposite those already present. The experiment began after an initial training period during which the pigeons were rewarded with food pellets for pecking the rear response key. In the basic procedure, both grain hoppers were active and the pigeon could either wait (5 or 15 s on alternate trials) for the LL reward or peck the original response key to receive the SS reward. The experiment involved three phases, differentiated by the function of the rear response key and rear hopper. During Phase A, the "no toy" condition, the rear key was inactive and covered with black tape. During Phase B, the "toy plus FR 20" condition, the rear key was lit and produced reinforcement, a single food pellet, according to a FR 20 schedule. And during Phase C, the "toy, no reinforcement" condition, the conditions were identical to "toy plus FR 20" except the rear response key never produced reinforcement. Two pigeons were used as subjects. One bird experienced the conditions in the order ABCA and the other in the order BACA. Each phase lasted between five and eight sessions.

Again, Grosch and Neuringer (1981) found that the behaviour of their pigeons was broadly similar to the behaviour exhibited by children in Mischel, Ebbesen and Zeiss (1972) study. In the no toy condition the birds rarely waited for the LL reward, showing self-control on only 4% of trials. However, the presence of an alternative response key (the toy) greatly improved self-control. In the toy plus FR 20 condition and the toy, no reinforcement condition the birds waited for the LL reward on 78% and 76% of the trials respectively. In addition, the rate of responding on the rear key was similar regardless of whether or not it produced reinforcement.

Although only two have been discussed here, all of the studies by Grosch and Neuringer (1981) produced results that closely paralleled the findings that Mischel and his colleagues had reported with children. Mischel sees the development of language and self-instruction as integral to self-control, but the similar findings resulting from Grosch and Neuringer's experiments with non-humans, must surely cast doubt on this explanation.

The experiments conducted under Mischel delay of gratification paradigm were designed to study the behaviour of children in realistic self-control situations. However, these studies could be criticised for being too simplistic, and not reflecting the conditions of self-control problems in everyday life.

2.3 The Time Periods of Choice

Logue (1988) reviewed the experimental literature of self-control and concluded that a choice in a self-control experiment could be characterised by four distinct time periods, shown in Figure 2-1.

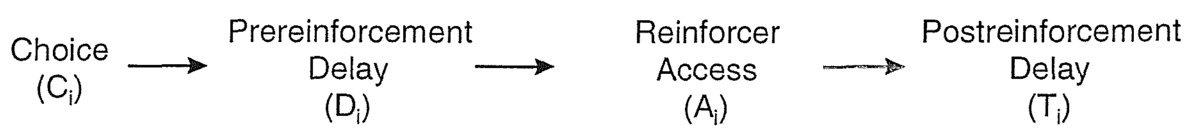

Figure 2-1. Time periods of a particular choice, i, in the self-control paradigm (Logue, 1988).

For a particular choice, i, there is initially a period of time during which the choice response must occur (C_i). Following the choice response there is a prereinforcement period (D_i) before the organism is allowed a period of access to the reinforcer (A_i). Finally, there is a postreinforcement period (T_i) before the next choice period (C_{i+1}) begins. Together, the duration of these four time periods (some of which may be set at zero) determine the overall frequency of reinforcement (F_i), shown in Equation 2-1.

$$F_i = \frac{1}{(C_i + D_i + A_i + T_i)} \qquad (2\text{-}1)$$

Logue (1988) stressed that each time period may have a bearing on self-control behaviour. However, in the typical delay of gratification experiment (Mischel et al., 1989), where children can wait for a preferred reward or make a signal to receive the less preferred reward, the only time period involved is the prereinforcement period. Also, because only one choice is made, the significance of the postreinforcement delay and the overall frequency of reinforcement are ignored. In comparison, experiments that have adopted an operant approach have demonstrated an awareness of all the time periods involved in choice. Generally, however, in these studies that involve repeated choice between SS and LL rewards, the postreinforcement delays of the two alternatives are arranged so that the time taken by both choices are identical, and so the choice frequencies are equal (e.g., Rachlin & Green, 1972). For example, if an experiment that uses a LL reward, a 6 s prereinforcement delay followed by a 4 s access to reward (total time 10 s), and a SS reward, a 1 s prereinforcement delay followed by a 3 s access to reward (total time 4 s), a 6 s postreinforcement delay will follow the SS reward so that the frequencies of both the alternatives are constant.

2.4 The Operant Approach to Self-control

The chapter continues with an brief overview of operant choice research, followed by a review of the experiments investigating the effects of reward delay and magnitude on choice with non-human subjects, and then those using human subjects. What follows is not intended to be an exhaustive survey of the research concerning self-control, let alone the wider literature on choice and the matching law (see chapter 1). To which end, explicit details of research exploring factors not immediately relevant to the question of temporal discounting or the experiments conducted for this thesis (chapters 5 - 8) have been excluded. The research not discussed includes those studies that have examined the effects of food preference on self-control in humans (e.g., Forzano & Corry, 1998; Forzano & Logue, 1994, 1995; Forzano, Porter, & Mitchell, 1997) and food deprivation in non-humans (e.g., Bradshaw & Szabadi, 1992; Ho, Wogar, Bradshaw, & Szabadi, 1997; Wogar, Bradshaw, &

Szabadi, 1997), although the importance of these factors with regards to self-control could not go unmentioned.

Under basic schedules of reinforcement the characteristic response patterns produced by non-humans and pre-verbal infants, and the different patterns produced by verbal humans, have been well documented (see Lowe, 1979, for review). However, when two or more reinforcement schedules are available simultaneously such that the organism can choose how to distribute responses, the resulting behaviour is more difficult to predict because behaviour is the product of simultaneous interactions with all the schedules of reinforcement that are concurrently available. In a comprehensive review of the literature, Mazur (1991) has reported that since the late 1950s, the number of research articles published in the *Journal of the Experimental Analysis of Behavior* which are described as investigating choice has steadily increased. Mazur estimated that choice was the subject of 39% of the journal's articles in the years 1987 - 1988, a proportion that has been maintained in the years 1997 - 1999. A sub-group of these choice studies are those that oppose SS and LL rewards and are designed to reveal the factors that influence self-control.

By the beginning of the 1970s, it had been established by research into the phenomenon of matching, that when organisms are faced with a choice between a SS reward and a LL reward then preference is dependent on both the magnitudes of the rewards and their delays (Baum & Rachlin, 1969; Chung & Herrnstein, 1967; Herrnstein, 1961, 1970). This fact was established by experiments that typically exposed non-humans (e.g., rats and pigeons) to concurrent variable interval, or VI, schedules. In an interval schedule, a minimum amount of time must elapse before a response is reinforced, and in a VI schedule, the time that must elapse before a response is reinforced is averaged around a particular interval. For example, Chung and Herrnstein (1967) studied the choice behaviour of pigeons who were exposed to two VI schedules. Initially, the birds were exposed to two VI 60 s schedules that delivered immediate reward until the rate of pecking had stabilised and was approximately equal. Delays were then added before the delivery of reinforcement on each schedule. On one schedule there was an 8 s delay preceding reinforcement, and on the other the delay varied between 1 and 30 s, depending on the session. The results showed that as the delay to reinforcement on the variable-delay schedule increased the relative frequency of responding on that schedule decreased from .82 with a 1 s delay to .15 with a 32 s delay. This finding indicates that the birds preferred immediate to delayed reinforcement.

Experiments using interval schedules have shown that an organism may prefer a SS reward, but this preference may be diminished or even reversed if the ratio of the reward sizes is increased, or if the ratio of their delays is reduced (see Herrnstein, 1981; Logue, 1988, for reviews). However, interval schedules do not model the SS versus LL conditions thought to characterise self-control.

A schedule frequently used in self-control research is the *chain schedule*, that is advantageous because it separates choosing from interaction with the chosen outcome. A chain schedule consists of a series of reinforcement schedules, often referred to as the *links* of the chain, that must be completed sequentially such that fulfilling the requirements of an entire link leads to the following link. Each link is associated with a different discriminative stimulus (e.g., a coloured light), but only the final link results in reinforcement. Usually, the first and last link in any chain schedule are called the *initial link* and the *terminal link* respectively. When two or more chain schedules are presented simultaneously the arrangement is called a *concurrent-chain schedule* (see Figure 2-2). Although, the theoretical number of permutations of different schedules and number of links is large, in practice, the most commonly used concurrent-chain schedule consists of only two chains, each composed of two links (e.g., Rachlin & Green, 1972). When gauging choice preference in this type of procedure, researchers usually measure responding only in the initial link because only at this time are both terminal link alternatives available. The most common behavioural measures are response rate and time allocation.

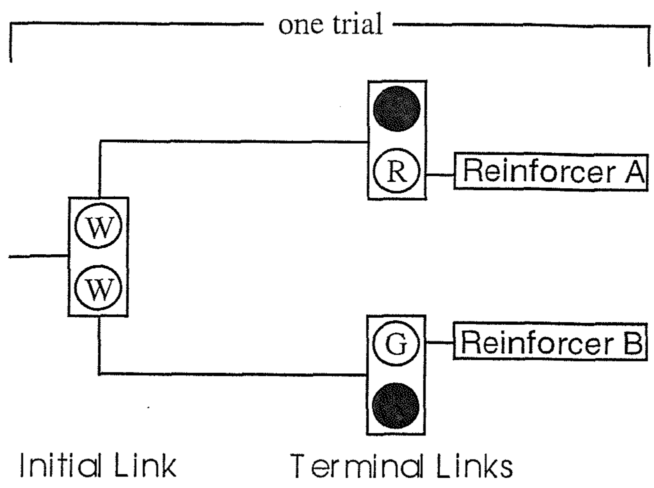

Figure 2-2. Schematic diagram of a concurrent-chain schedule consisting of an initial link and two alternative terminal links. The circles represent manipulanda, typically either response keys or levers, and the letters within show that they are associated with different discriminative stimuli. Commonly, manipulanda are differentiated by coloured lights: (W)hite, (R)ed, and (G)reen in the example. Depending on how the requirements of the initial link are fulfilled the chain progresses to one of the two terminal links. If the chain progresses along the upper path then fulfilling the requirements of the terminal link leads to the delivery of reinforcer A. If the chain progresses along the lower path then fulfilling the requirements of the terminal link leads to the delivery of reinforcer B.

2.5 Non-human Studies: Effects of Reward Magnitude and Delay

2.2.1 Temporal Discounting and Commitment

In what has now become a seminal paper, Rachlin and Green (1972) investigated self-control behaviour in pigeons. Specifically, Rachlin and Green's study was designed to determine whether the birds would used a commitment strategy that prevented access to the SS reward in order to guarantee the LL reward in a self-control paradigm. The design, illustrated in Figure 2-3, used a concurrent-chain procedure in which the initial link offered progression to two potential terminal links. One terminal link consisted of the standard SS versus LL self-control choice while the other only allowed access to the LL reward.

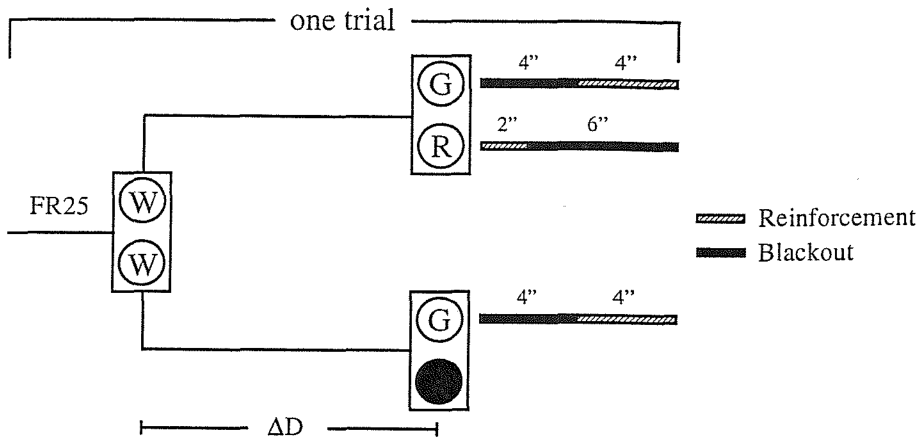

Figure 2-3. Schematic diagram showing the choices available to a pigeon in Rachlin and Green's (1972) study of commitment. The circles represent response keys in an experimental chamber, and the letters within show how they were illuminated: (W)hite, (R)ed, or (G)reen. The initial link required 25 responses on either of the two keys, both illuminated white. The 25th response was followed by a blackout of ΔD s, the inter-link delay, and determined progression to either the uncommitted (upper path) or committed (lower path) terminal link. During the uncommitted terminal link, a peck to the green key produced a larger-later reward while a peck to the red key produced a smaller-sooner reward. During the committed terminal link, a peck to the green key produced a larger-later reward while the other key remain dark and inactive.

Rachlin & Green (1972) used an operant conditioning chamber containing two response keys. The subjects were 5 adult, male pigeons. Each day, the food-deprived birds (80% of free-feeding weight) were placed in the experimental chamber and experienced 10 forced-choice trials and 40 free-choice trials. Progression from the initial link to the terminal link was on a fixed-ratio 25 (FR 25) schedule. During the initial link of the forced-choice trials, the purpose of which was to ensure that the pigeons experienced both of the alternative paths to reward, only one response key was active and illuminated with white light. The birds experienced 5 trials where they were forced to choose the uncommitted terminal link and 5 where they were forced to choose the committed terminal link. In comparison, during the initial link of the free-choice trials the birds' had a choice because both keys were illuminated and led to their respective terminal links.

Completion of the initial link resulted in a blacked out inter-link delay period (ΔD in Figure 2-3), the duration of which varied according to the session. Following the blackout the terminal link began. During the terminal link only one key-peck response (FR 1) was required to produce a reinforcer. If the initial link finished on the right response-key then in the terminal link both keys were re-illuminated, one lit with red light and the other with green (upper path in Figure 2-3). Which key was red and which was green was determined randomly on each trial. The red key produced a SS reward: 2 s access to grain followed by a 6 s blackout. The green key produced a LL reward: a 4 s blackout followed by 4 s access to grain. Alternatively, if the initial link finished on the left response-key then in the terminal link only one key, randomly assigned, was re-illuminated with a green light (lower path in Figure 2-3). If pecked, this green key produced a LL reward identical to the other terminal link. The other key remained dark and inactive (i.e., no SS reward was available). The completion of both terminal links was followed by the beginning of the next trial.

In Rachlin and Green's (1972) study, the lower path represented in Figure 2-3 is, in essence, a laboratory-based instantiation of a commitment strategy, where a response made during the initial link removes the opportunity to chose later in the terminal link.

The results of this ingenious experiment showed that when exposed to a terminal link comprising a traditional SS versus LL self-control choice the birds invariably behaved impulsively (i.e., choose the SS reward). However, the pigeons' behaviour during the initial link was found to be dependent on the duration of the blacked-out inter-link delay between the end of the initial link and the beginning of the terminal link. The inter-link delays studied ranged between 0.5 and 16 s and were systematically varied every 10 sessions. The averaged data showed that when the inter-link delay was below 4 s the birds' response rate was highest on the right key, that led to the unconstrained SS versus LL terminal link, but when the delay was greater than 4 s the response rate was highest of the left key. These results support the notion of preference reversal stemming from the hyperbolic discounting of delayed rewards as the delay to both rewards is increased by a similar amount (e.g., Baum & Rachlin, 1969). However, it also provides evidence that pigeons can show self-control if given the opportunity to commit to the LL reward at a time before the discounted values of the two alternative intersect.

Ainslie (1974) queried whether Rachlin and Green's (1972) use of a FR 25 schedule during the initial link may have had an influence on the pigeons' behaviour because the time taken by most of the birds to make 25 responses was longer than the longest possible delay to which the birds could commit. Ainslie argued that, in a sense, the "immediate" reward was not truly immediate. To overcome this potential confound, Ainslie replicated Rachlin and Green's experiment but changed the initial link so that progression to the terminal link was dependent on just a single response (FR 1). However, despite this revised design, Ainslie found a similar pattern of behaviour, adding weight to Rachlin and Green's earlier findings.

These two studies, by Rachlin and Green (1972) and Ainslie (1974), have become cornerstones in the behavioural approach to self-control. They successfully demonstrated the relevance of temporal discounting to the problem of self-control and impulsiveness, and they also showed that animals can employ a form of commitment strategy to ensure the LL reward is obtained.

An alternative, less restrictive method of commitment, recognised in human behaviour, involves arranging a punishment to be contingent on the undesired behaviour. Green and Rachlin (1996) modified their earlier design (Rachlin & Green, 1972) to study this form of commitment in pigeons. In addition to the standard SS and LL rewards, Green and Rachlin introduced a third alternative, a SS reward followed by the punishment of an extended blackout (Smaller-Sooner-Punisher, or SSP). The apparatus consisted of an experimental chamber containing three response keys, and the subjects were 5, male, adult pigeons. Commonly, in schedule-based experiments, the subjects are all exposed to identical rewards. However, in the initial stages of this experiment the rewards where determined individually so that each bird consistently chose SS reward over LL reward, which in turn was consistently chosen over SSP reward. Throughout the study, each reward was associated with a particular coloured response key: the SS reward with red, the LL reward with green, and the SSP reward with yellow.

The study used a concurrent-chain procedure, an illustration of which is shown in Figure 2-4. Each session the birds experienced 8 forced-choice trials followed by 40 experimental trials. During the initial link of the experimental trials, both the left and right response keys were illuminated with white light, while the centre key remained unlit. The forced-choice trials were distinct because only one of the keys was lit during the initial link and ensured that the birds experienced both the punished and unpunished terminal links. Progression to the terminal link, that was preceded by a variable inter-link delay during which all three key were unlit, occurred on the third peck to one of the white keys (independent FR 3). If the initial link was completed on the left key, the terminal link consisted of the standard self-control choice, SS versus LL, with the left key illuminated red and the centre key green. If the initial link was completed on the right key, the terminal link included the SSP reward instead of the normal SS reward. During the terminal link, delivery of reward was again dependent on an independent FR3 schedule.

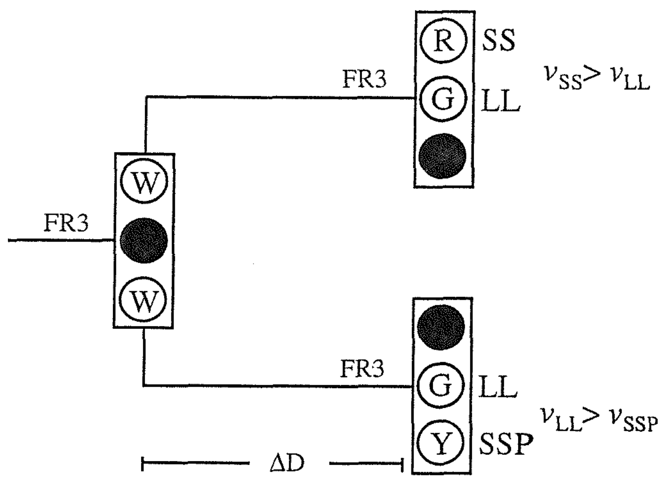

Figure 2-4. Schematic diagram of the choices available to a pigeon in Green and Rachlin's (1996) study of commitment through punishment. The circles represent response keys in an experimental chamber, and the letters within show how they were illuminated: (W)hite, (R)ed, (G)reen, or (Y)ellow. The initial link was an independent fixed-ratio 3 schedule (FR 3) and was followed by a blackout of ΔD s and progression to either the unpunished (upper path) or punished (lower path) terminal link. The outcomes of the terminal links were also dependent on an independent FR 3 schedule. In the unpunished terminal link, the red key produced a smaller-sooner (SS) reward while the green key produced a larger-later (LL) reward. In the punished terminal link, the green key produced a LL reward while the yellow key produced a SSP reward, consisting of the standard SS reward followed by a blackout (the punishment). Before testing, the rewards for each pigeon were assessed so that the value (v) of the SS reward was greater than the LL reward and the LL reward was greater than the SSP reward.

Unsurprisingly, because the relative value of the rewards were scaled in the first part of the experiment, the birds nearly exclusively chose SS during the unpunished terminal link and LL during the punished terminal link. The significant finding of this study, however, is that as the delay between initial and terminal links increased the birds chose the alternative that included punished terminal link (i.e. showed commitment) more frequently. Thus, this form of commitment functioned like physical restraint, although it was less powerful: even after choosing the punished route, the birds occasionally chose the SSP reward despite the consequences.

2.2.2 *Experience-based Differences*

Rachlin and Green (1972) and Ainslie (1974) found evidence supporting the theory that an organism will precommit to a LL reward if the opportunity arises before the discounted values of the SS and the LL rewards crossover. However, the performance of the pigeons studied in these two experiments was far from uniform. The birds showed individual differences in the duration of the delays that resulted in commitment, and Ainslie reported that when he was selecting pigeons to act as subjects in his experiment, some completely failed to show commitment when tested. Such individual differences in self-control behaviour clearly need to be explained.

There is experimental evidence that the effects of delay on behaviour are dependent on the previous experience an animal has had with delayed rewards (Ferster, 1953). Mazur and Logue (1978) further investigated this phenomenon. They designed an experiment that implemented a fading procedure, in which the delay to the smaller reward in a typical self-control choice paradigm was gradually decreased from 6 to 0 s. Eight food-deprived pigeons were tested individually in an experimental chamber containing two response keys. Figure 2-5 shows a schematic diagram of the experimental design. The left key was illuminated with green light and the right key with red light. Reward was dependent on a FR 1 schedule. A peck on the green key produced the LL reward; both keys darkened and the bird experienced a prereinforcement delay of 6 s followed by 6 s access to grain. A peck on the red key produced the smaller reward; both keys darkened and the bird experienced a variable prereinforcement delay period followed by 2 s access to grain. The delay period preceding the smaller reward was the independent variable and was varied over the course of the experiment while the delay to the larger reward remained constant. Each session the pigeon experienced 34 trials, on 3 of which (trials 10, 20 and 30) the birds were forced to experience the smaller reward. During these forced-choice trials only the red key was lit and active.

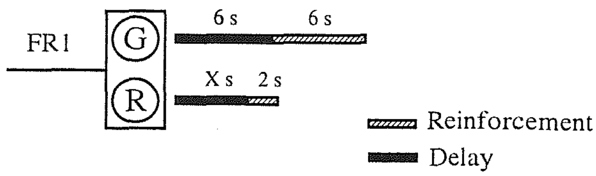

Figure 2-5. Schematic diagram of the choices available to a pigeon in Mazur and Logue's (1978) experiment. The circles represent response keys in an experimental chamber, and the letters within show how they were illuminated: (G)reen, or (R)ed. Access to reinforcement (grain) was determined by an FR 1 schedule. The green key resulted in a larger-later reward that consisted of a 6 s delay followed by 6 s reinforcement. The red key resulted in a smaller-sooner reward that consisted of a delay followed by 2 s reinforcement. The delay was decreased from 6 to 0 s over a number of sessions.

Birds assigned to an experimental group initially experienced a choice between the LL reward and a smaller reward both delayed by 6 s. Over the course of more than 11000 trials (over 300 sessions), the delay preceding the smaller reward was gradually reduced to nothing. In comparison, a control group only experienced two conditions. The controls began with no delay preceding the smaller reward (24 sessions) and than changed to a delay of 5.5 s (28 sessions). In all conditions, the post-reinforcement delay was controlled so that each trial was of a constant length regardless of the choice and maximum reward was thereby obtained by exclusively choosing the LL reward on each trial.

In both the experimental and the control conditions, the birds nearly exclusively chose the LL reward when the delay period preceding the smaller reward was 3.25 s or longer. However, when the smaller reward was immediately available, the two groups showed significant differences in behaviour. Whereas the control birds were consistently impulsive, those birds that had experienced the fading procedure still chose the LL reward on a large proportion of the trials. These results, and those from a subsequent study by Logue, Rodriguez, Pena-Correal, and Mauro (1984) that replicate them, clearly showed that a fading procedure can increase self-control, and highlighted the importance of previous experience of obtaining delayed rewards on subsequent self-control behaviour. Although Rachlin and Green (1972) proved that animals could show self-control by pre-committing, the significance of this study was to show that under certain conditions some pigeons can be trained to show self-control without obvious commitment strategies. In terms of hyperbolic discounting, this study indicated that a simple inverse relationship between delay and reinforcer value was too simplistic to explain behaviour.

2.2.3 Summary of Non-human research

Non-humans (pigeons) tested in self-control experiments often behave impulsively. Although they prefer a larger reward over a smaller reward when both are available simultaneously, as the prereinforcement delay preceding the larger reward increases, preference shifts to the smaller but more immediate reward (Ainslie, 1974; Rachlin & Green, 1972). This preference reversal is predicted by theories that assume temporal discounting of delayed rewards (see Ainslie & Haslam, 1992; Herrnstein, 1981). Self-control by pigeons in free-choice situations that would usually produce impulsive behaviour has been shown but only after exposure to a year long fading procedure (Logue et al., 1984; Mazur & Logue, 1978). However, perhaps most importantly, it has shown that pigeons will employ commitment strategies to ensure that they obtain a LL reward under conditions where they would usually behave impulsively and choose the SS reward (Ainslie, 1974; Green & Rachlin, 1996; Rachlin & Green, 1972).

2.6 Human Studies: Effects of Reward Magnitude and Delay

2.3.1 Design differences between Human and Non-human studies

Although the SS versus LL paradigm has also been used extensively with human participants, human complexity — particularly the capacity for verbal behaviour — has allowed for greater variation in experimental design. For example, in many experiments using human participants, instructional manipulation has replaced prolonged exposure to the contingencies (e.g., Solnick, Kannenberg, Eckerman, & Waller, 1980). In these studies, participants are usually provided with a verbal description of the contingencies, following which they typically experience a behavioural task that requires them to make a choice between the described SS and LL rewards (e.g., Mischel et al., 1989). However, whereas operant research using non-humans typically involves positive reinforcement with primary reinforcers (e.g., access to food), conditioned reinforcers (e.g., tokens often exchangeable with money at the end of the experiment) are often used in human research. Alternatively, in some cases, a verbal dependent variable is also used, the participant being required to state a preference for the either the SS or the LL alternative (e.g., Rachlin, Raineri, & Cross, 1991; Raineri & Rachlin, 1993).

2.3.2 Temporal Discounting and Commitment

One of the first studies to question whether the findings from self-control research using non-humans could be extrapolated directly to explain human behaviour was conducted by Burns and Powers (1975). This experiment attempted to replicate Rachlin and Green's (1972) study as closely as possible, with only those modifications necessitated by the change of species. The design, illustrated in Figure 2-6, used a concurrent-chain procedure. One terminal link (the uncommitted) consisted of a standard SS versus LL choice while the other (the committed) only allowed access to the LL reward.

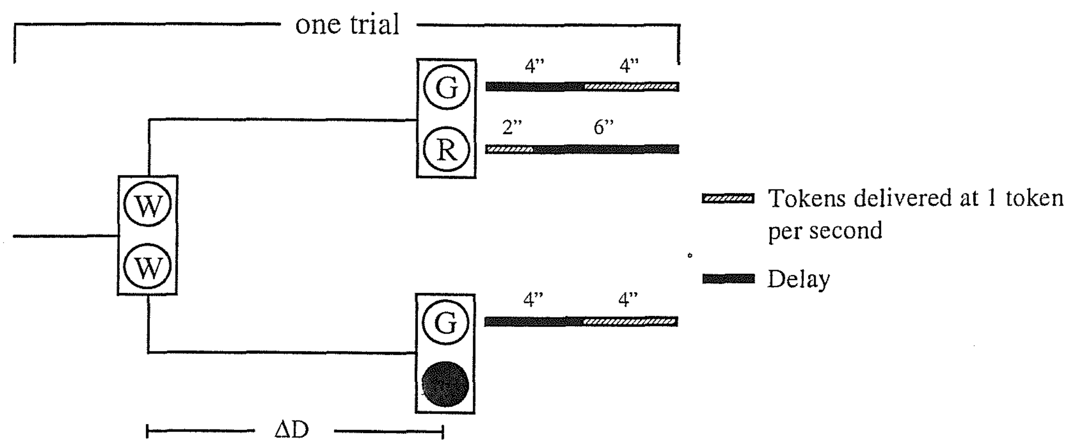

Figure 2-6. Schematic diagram showing the choices available to the children in Burns and Powers' (1975) study of commitment. The circles represent stimulus displays marking response levers. The letters within each circle show how these displays were illuminated: (W)hite, (R)ed, or (G)reen. In the initial link, pressing either of the white levers led to an inter-link delay period of ΔD s during which all the stimulus displays were dark. However, after ΔD, the terminal link depended on which lever was pressed during the initial link. During the uncommitted terminal link, pressing the green lever produced a larger-later reward (4 s delay followed by 4 tokens delivered over 4 s) while pressing the red lever produced a smaller-sooner reward (2 tokens delivered over 2 s followed by 6 s delay). During the committed terminal link, pressing the green lever produced a larger-later reward while the other stimulus display remain dark and the lever inactive.

The apparatus used by Burns and Powers (1975) consisted of console, housing two stimulus displays that could be lit either white, red, or green. Beneath each stimulus display was a response lever and connected to the console was a token dispenser that dispensed tokens at a rate of 1 per second. Tokens were exchangeable for $0.05. The participants were

2 male children, aged 9- and 10-years-old. During the initial session of the experiment, each participant received 10 forced-choice trials on each of the two alternative pathways to reward. Subsequent sessions consisted of 24 trials. The first 4 trials were forced-choice, in which the two alternative pathways were alternately experienced, followed by 20 free-choice trials, during which both pathways were accessibly. Following a lever press in the initial link, the stimulus displays darken and the levers became unresponsive for the inter-link delay period (ΔD in Figure 2-6). The inter-link delay was varied after at least every 4 sessions, and the children were exposed to delays of 0, 4, 8, 12, 16, 32 and 64 s. The left lever led to the uncommitted terminal link (upper pathway in Figure 2-6) and the right lever led to the committed terminal link (lower pathway in Figure 2-6). During the terminal link, the red lever produced a SS reward consisting of the delivery of 2 tokens followed by a 6 s delay, and the green lever produced a LL reward, consisting of a 4 s delay followed by the delivery of 4 tokens. The completion of both terminal links was followed by the beginning of the next trial.

The findings of Burns and Powers (1975) do not replicate those of Rachlin and Green (1972). Whereas Rachlin and Green found that as the inter-link delay increased their pigeons' preference changed from the uncommitted to the committed terminal link, Burns and Powers found that their participants' preference for the uncommitted terminal link increased. Thus, unlike pigeons, the children did not utilise the available commitment strategy. However, the children did show a preference reversal. When the inter-link delay was 4 s and below, the children's preference in the terminal link was for the LL reward, but at 8 s and above, the children's preference was for the SS reward. The study of Burns and Powers, therefore, demonstrates that although temporal discount does seem to explain human behaviour, children do not readily employ commitment strategies.

Solnick et al. (1980) also tried to replicate Rachlin and Green's (1972) experiment with human participants. In preliminary studies, they were unable to produce impulsive behaviour in their participants when using money as the reward, but they were able to do so by exposing their participants to a choice situation based on negative reinforcement, the termination of an white noise. Participants were told that the experiment was designed to investigate the effects of noise pollution on "intellectual performance". The contextual framing of the task was used to reduce possible differences in social desirability between the SS and LL rewards. The task involved the participant completing a series of maths problems while being subjected to loud white noise. Participants could terminate the noise for different periods of time depending on which button they pressed on a response panel. Solnick et al.'s first experiment was designed to determine whether humans showed the characteristic preference reversal predicted by temporal discounting. The response panel consisted of two buttons, distinguished by a green and a blue light positioned above them. A schematic diagram of single trial is shown in Figure 2-7. The green button resulted in the SS reward, 90 s of silence followed by 90 s of the aversive noise, and the blue button resulted in the LL reward, 60 s of the aversive noise followed by 120 s of silence. Participants experienced 25 trials, each of which began with a 15 s period of the aversive noise, during which the choice was made, followed by whichever reward, either the SS or the LL, the participant chose.

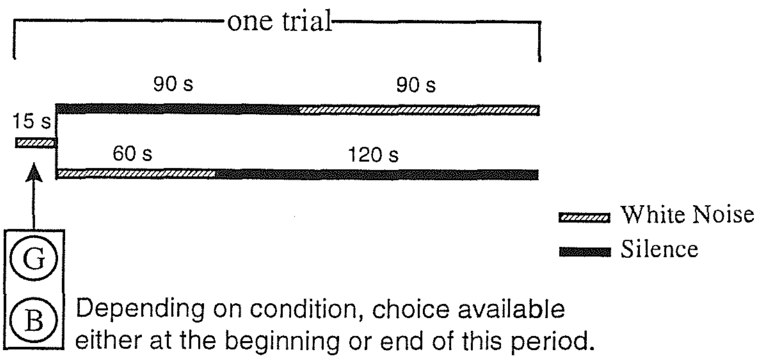

Figure 2-7. Schematic diagram of the Solnick et al. (1980), Experiment 1. Depending on the condition, the self-control choice was either available at the beginning or the end of the initial 15 s period of white noise. The circles and letters represent buttons marked with coloured lights on the response panel. Pressing the (G)reen button produced a smaller-sooner reward and pressing the (B)lue button produced a larger-later reward.

Solnick et al. (1980) manipulated two independent variables in a between-subject design. The first variable was the point at which the self-control choice could be made. This was either at the beginning or the end of the initial 15 s period of noise, and was indicated by the room light turning off until one of the buttons had been pressed. This signal also served to prevent the participants from simply continuing with the maths problems when a choice was required. The second variable involved an instructional manipulation. All the participants were told that the green button produced the more immediate cessation of noise (immediacy only group) but, in addition, half the participants were also told specifically that the blue button produced the longest cessation (immediacy and duration group).

The main finding of Solnick et al.'s (1980) first study was that the immediacy and duration group showed an almost exclusive preference for the LL reward when the choice point occurred at the beginning of the initial period and an almost exclusive preference for the SS reward when the choice point occurred at the end of the initial period. Such a preference reversal, when participants were told how to minimise the duration of the white noise, seems counterintuitive but is predicted by the hyperbolic discounting theory. In comparison, however, the choices made by the immediacy only group were not significantly affected by the choice point, and thus did not show preference reversal. Navarick (1982) subsequently suggested that the lack of effect between these immediacy only groups may have been caused by the maths problems distracting attention from the temporal characteristics of the schedules. However, Solnick et al. (1980) preferred to concentrate on the immediacy and duration group, concluding that this study provided "tentative" evidence that human behaviour is sensitive to changes in reward delay and magnitude, but that the effect of the instruction manipulation suggested that the control by the contingencies was facilitated by the additional verbal descriptions.

The findings of Solnick et al.'s (1980) first experiment were further supported by the findings of their second, in which an alternative LL reward, comprising of 30 s of noise followed by 150 s of silence (same overall duration as 60 s noise followed by 120 s silence), was compared to the LL reward used in the first experiment, and an intermediate choice point was added so that participants chose at either 0, 7.5, or 15 s from the beginning of the trial. All the participants in this experiment received immediacy and duration instructions. The results again showed the preference reversal from the SS reward when the choice point was at the end of the initial period of white noise to the LL reward when the choice point was at the beginning of the initial period. In addition, preference for the LL was greatest when silence was 150 s as opposed to 120 s. Whether this effect was caused by the change in duration of the reinforcement period, or the prereinforcement period, or an interaction between the two, is unclear. However, the results are consistent with predictions based on hyperbolic discounting that would predict that the value of the 150 s silence reward would be greater at the choice point than the 120 s silence because it is both more immediate and of greater magnitude.

Having established that human participants sometimes exhibited preference reversal when the delays preceding both a SS and LL reward were increased by the same amount, Solnick et al.'s (1980) third experiment developed their design to incorporate a response that was equivalent to the commitment strategies that Rachlin and Green (1972) used in their study with pigeons. A schematic diagram of this experiment is shown in Figure 2-8. Two groups of participants experienced conditions previously described in experiment 1 above, and represented solely by the pathway in Figure 2-8. Both these groups received immediacy and duration instructions, and one group had to make their choice at the beginning of the initial 15 s period and the other had to make their choice at the end. A third group experienced the commitment condition, and were given the opportunity to commit to the LL reward at the beginning of each trial. At the beginning of the initial 15 s period, the participants could operate a switch, the initial link in the chain schedule, that determined whether they progressed to the upper (uncommitted terminal link) or lower path (committed terminal link) of Figure 2-8. If they flicked the switch one way then at the end of the initial 15 s they had an unrestricted choice between the SS and LL rewards, and if they flicked the switch the other way then at the end of the initial period they could only obtain the LL reward.

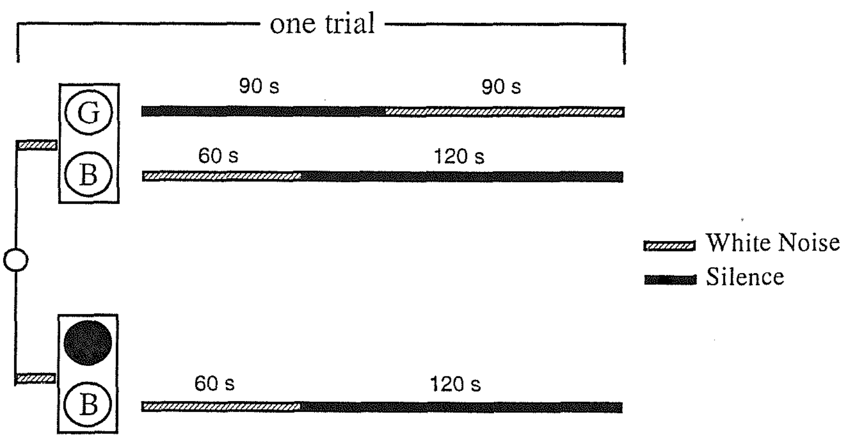

Figure 2-8. Schematic diagram showing the choices available to participants in Solnick et al.'s (1980) study of commitment. The small circle represents a switch that determined whether the participants progressed via the upper of lower pathway. The circles and letters represent buttons marked with coloured lights on the response panel. Pressing the (G)reen button produced a smaller-sooner reward and pressing the (B)lue button produced a larger-later reward.

As a group, participants in the commitment condition did not commit themselves to the restricted choice on more occasions than would be predicted by chance. However, Solnick et al. (1980) felt that this group analysis obscured the behaviour of individuals, and noted that participants in the commitment condition could be subdivided in those who precommitted on more than 60% of trials and those precommitted on less than 40%. Why some participants chose to commit more than others is unclear. Nevertheless, in those trials in which they failed to precommit to the LL reward and thus had a self-control choice at the end of the initial period, these participants still chose significantly more LL rewards than those participants in the non-commitment condition who also had to choose at the end of the initial period. Consistent with the findings of their first and second experiments, those participants in the non-commitment conditions who had to choose at the beginning of the initial 15 s period chose significantly more LL rewards than those who had to chose at the end.

Solnick et al. (1980) concluded that their results were at least qualitatively similar to those of Rachlin and Green (1972), showing that humans are sensitive to changes in reward delay and magnitude, and can implement commitment strategies to ensure self-control. But, Solnick et al. also recognised that fact that there were strong individual differences between participants, for which they could not account. However, overall, the experiments performed by Solnick et al. do not seem to provide convincing evidence that human behaviour can be explained by temporal discounting.

Navarick (1982) noted that quantitative models of choice such as the matching law make certain basic predictions. Firstly, they predict that the larger of two reinforcers will be preferred if the delays until their delivery are equal, and the more immediate reinforcer will be preferred if they are not. Secondly, a larger reinforcer will be preferred to a smaller reinforcer if both are equally delayed, but if the delay preceding the LL reinforcer is increased then at some point preference will reverse. Navarick observed that although Solnick et al. (1980) found evidence that could be interpreted as demonstrating temporal discounting in humans, a more formal investigation of these basic predictions with human participants was required. To address this need, Navarick conducted an experiments in which the delay and magnitude of opposed rewards were systematically varied between-subjects.

Navarick (1982) exposed the participants to aversive levels of white noise that they could terminate (silence) for different periods of time depending on their choices. Participants were tested in an experimental cubicle that contained a table, mounted on which were two response keys. Each trial began with a 10 s period of noise during which time both response keys were unlit. Following this initial period the choice period began, during which the white noise continued and the two response keys were lit red. When a participant operated one of the responses keys, both keys darkened and the outcome phase of the trial began. In each condition, the postreinforcement period of noise following the immediate reward was set so that the trial length resulting from both alternatives was the same, and thus the overall reward was maximised by consistently choosing the larger reward. Some conditions yielded longer trials, but because Navarick did not wish to inconvenience his participants by conducting sessions longer than 60 min, so those conditions with the longer trial lengths had a reduced number of trials.

Seven groups of participants chose between opposed outcomes, summarised in Table 2-1, that were arranged to test the two basic prediction matching law stated above. To test the first prediction, that participants would prefer the more immediate of two rewards of equal magnitude, Groups 1 and 2 experienced two rewards of 20 s silence, one immediately available and one delayed by either 20 or 40 s, for Groups 1 and 2 respectively. The results were consistent with those predicted. By the last quarter of the session, both Groups 1 and 2 exhibited exclusive preference for immediate over the delayed reward. To test the second prediction, that the participants' preference for an immediately larger reward will decrease as that reward becomes more delayed, Groups 3 to 7 experienced an immediately available small reward of 5 s silence and a larger reward of 20 s silence, the delay to which was progressively increased between the groups from 0 to 75 s. Again the results were consistent with those predicted. Group 3, for who both rewards were available immediately, showed an almost exclusive preference for the larger one. However, as the delay preceding the larger reward was increased across Groups 4 to 7, the participants' preference gradually shifted towards the smaller reward, so that Group 7 who experienced a prereinforcement period of 75 s were almost exclusively choosing the immediate but smaller reward.

Table 2-1

Principal groups in Navarick (1982)

Group	Schedules			Trial length (s)
1	20 s silence, 20 s noise	vs.	20 s noise, 20 s silence	40
2	20 s silence, 40 s noise	vs.	40 s noise, 20 s silence	60
3	5 s silence, 35 s noise	vs.	20 s silence, 20 s noise	40
4	5 s silence, 35 s noise	vs.	20 s noise, 20 s silence	40
5	5 s silence, 55 s noise	vs.	40 s noise, 20 s silence	60
6	5 s silence, 75 s noise	vs.	60 s noise, 20 s silence	80
7	5 s silence, 90 s noise	vs.	75 s noise, 20 s silence	95

The findings of Solnick et al. (1980) and Navarick (1982) supported the view that human impulsivity is analogous to impulsivity found in non-humans (e.g., Rachlin & Green, 1972), in that it results from the discounting of future rewards in ways that can be quantitatively modelled by the matching law (Herrnstein, 1981). However, Millar and Navarick (1984) and Logue, Peña-Correal, Rodriguez, and Kabela (1986), noted the fact that whereas Solnick et al. and Navarick both used negative reinforcement, non-human studies typically used positive reinforcement, and decided that this methodological discrepancy warranted further research.

Millar and Navarick (1984) developed a self-control experiment based around access to a computer game, called "Worm", as a positive reinforcer. This, they believed, more closely resembled reinforcers typically used in non-human studies (i.e., food and water) because it required interaction with a stimulus for a specific length of time and, to an extent, was also intrinsically reinforcing. Each trial consisted of a period of access to the video game (play) and a waiting period, during which the screen was blank except for the word "wait". At the end of each trial, the participant was prompted by an on screen message to press one of two button on the keyboard, each of which resulted in a different arrangement of playing and waiting depending on the specific condition. There were 4 principal groups, each of 10 participants. The alternative outcomes the participants could choose between in each of these groups are summarised in Table 2-2. Group 1 experienced a choice between immediate and delayed reinforcement, the reinforcers being of equal magnitude. Group 2 experienced a choice between two immediate reinforcers of different magnitude. Group 3 experienced a (self-control) choice between a smaller, immediate reinforcer and a larger but more delayed reinforcer. Trial length across these three groups was constant so that maximising game play, the reward, was obtained by consistently choosing the larger, delayed reward. Group 3A, also experienced a choice between a smaller, immediate reinforcer and a larger, delayed reinforcer but there was no postreinforcement delay following the delivery of the smaller reward, so the next trial began immediately. The rate of reinforcement for with the SS reward was, therefore, 16 times greater than in Group 3, and maximum game play was achieved by repeated choosing it.

Table 2-2

Principal groups in Millar and Navarick (1984)

Group	Schedules			Trial length (s)
1	play 20 s, wait 40 s	vs.	wait 40 s, play 20 s	60
2	play 10 s, wait 40 s	vs.	play 40 s, wait 10 s	50
3	play 10 s, wait 150 s	vs.	wait 120 s, play 40 s	160
3A	play 10 s, wait 0 s	vs.	wait 120 s, play 40 s	10 vs. 160

The participants in Group 1 preferred immediate to delayed reinforcers when the magnitudes were equal and the participants in Group 2 preferred larger to smaller reinforcers when both were immediately available. These are the results that the matching law would have predicted. The participants in Group 3 showed no statistical preference between the SS and the LL reinforcers, and therefore provided no evidence of impulsivity. However, compared to those participants in Group 2 who experienced rewards of the same magnitude, Group 3 showed a greater preference for SS reward, that Millar and Navarick interpreted as demonstrating a limited degree of impulsivity. In Group 3, because the length of each trial was constant, choosing the smaller reward resulted in less reward overall. However, in comparison, in Group 3A the smaller reward was not followed by a waiting period and therefore resulted in a much greater rate of reinforcement. The results showed that under this condition preference for the smaller reward was almost complete.

Following Millar and Navarick's (1984) relatively unsuccessful attempt to demonstrate impulsivity in humans when using positive reinforcement, Logue et al. (1986) conducted a series of experiments designed to further explore human sensitivity to reward magnitude and delay under positive reinforcement. In these experiments, participants had to operate a lever to receive points that were exchangeable for money on completion of the experiment. Rewards were delivered in accordance to two concurrent VI schedules. The specific details of the outcomes of these schedules are too numerous to reproduce here, but they were systematically varied in terms of reinforcer amount and prereinforcement delay so as to test predictions made by the matching law. From these experiments, Logue et al. found no evidence to support temporal discounting in humans; participants tended to maximise reinforcer amount regardless of delay. To explain these findings, Logue et al. suggested, as previously discussed by Lowe (1979), that the difference in performance between non-human and human subjects on various schedules of reinforcement are potentially due to humans generating and following their own verbal rules.

Other researchers have also produced experimental findings that challenge the assumption that temporal discounting provides an explanation of human behaviour. Sonuga-Barke, Lea and Webley (1989c) noted that in those self-control studies in which the experimental sessions terminated after a fixed period of time (e.g., Navarick, 1982), maximisation of reward depended on choosing the alternative that resulted in the higher density of reinforcement. To calculate the density of reinforcement requires the participant to take into account all the time periods of a particular choice: choice, prereinforcement delay, reinforcer access and postreinforcement delay (see Logue, 1988). Rather than being the result of temporal discounting, Sonuga-Barke et al. (1989c) argued that impulsivity in some experiments may simply be the result of a miscalculation of the relative reinforcement densities of the opposed rewards. Several experiments by Sonuga-Barke, Lea and Webley (1989a, 1989b, 1989c) support their miscalculation theory; the key studies are discussed below.

Sonuga-Barke, Lea and Webley (1989a) investigated the relationship between age and self-control in an operant self-control paradigm that opposed SS and LL rewards. The participants in this study were 16 females children, four at each of four ages, 4-, 6-, 9-, and 12-years-old. Where this experimental design departed from contemporary studies (e.g., Navarick, 1982; Solnick et al., 1980) was that there was no postreinforcement delay period following either outcome, so that the next trial began immediately following the delivery of reward. As the rate of reinforcement is a function of all four time periods of a particular choice (Logue, 1988), this meant that if the prereinforcement delay of the larger reward was larger than the prereinforcement delay of the smaller reward then it was possible that more reward overall could be obtained by consistently choosing the SS reward because of the higher density of reinforcement it offered. Under such conditions, what is defined as impulsive behaviour under the SS versus LL model becomes the adaptive response (i.e., leads to maximising reward).

The apparatus was a computer housed in a portable box from which only the monitor could be seen. Located below the monitor, separated by a token dispenser, were two buttons, one red and one blue. Each participant took part in five 15 min sessions during which concurrent-chain schedules determined the delivery of tokens, that the children could later exchange for toys and sweets. The start of each initial link was indicated by coloured arrows displayed on the monitor that pointed at the appropriate response buttons. Responses were reinforced according to two independent VI schedules, each associated with a particular response button. At the beginning of the session the schedule intervals were set at 0 s and gradually increased to a maximum of 10 s as the session progressed. This fading procedure was used because it was found to reduce superstitious behaviour often produced by human participants in operant studies that involve responding on schedules of long duration (see Sonuga-Barke et al., 1989b, for details). On fulfilment of the initial link, the terminal link appropriate to the response button pressed began. One response button led to a terminal link that resulted in a SS reward, comprised of a 10 s prereinforcement delay followed by the delivery of 1 token. The other button led to a terminal link that resulted in a LL reward, comprised of a session dependent prereinforcement delay of either 20, 30, 40, or 50 s followed by the delivery of 2 tokens. Because the next trial began immediate after the delivery of reward (i.e., there was no postreinforcement delay), the reward rate was dependent on the prereinforcement delay. Thus, when the LL delay was 20 and 30 s, the maximum number of tokens were obtained by consistently choosing the LL reward. When the LL delay was 40 s, consistent choice of either reward delivered the same number of tokens. However, when the LL delay was 50 s the relative rates of reward were such that consistent choice of the SS reward yielded the greatest number of tokens. The reward alternatives and the relative amounts of reinforcement per session are summarised in Table 2-3. Following each session the children were asked which alternative they preferred and to explain why.

Table 2-3

From Sonuga-Barke et al. (1989a), total number of tokens available per 15 minute session given exclusive choice preference of either the Smaller-sooner or Larger-later reward

Reward	Reinforcement delay (s)	Tokens per choice	Trials per session	Tokens per session
Smaller-sooner	10	1	30	30
Larger-later	20	2	22.5	45
	30	2	18	36
	40	2	15	30
	50	2	12.9	25.8

Sonuga-Barke et al. (1989a) found that task performance at different ages was dependent on different aspects of the schedules. Both the 6- and 9-year-old children tended to choose the larger reward regardless of the prereinforcement delay. This meant that in the condition where the LL followed a 50 s delay, the children failed to maximise the available reward despite that fact that, under the traditional definition, they were exhibiting self-control. In comparison, the behaviour of the 12-year-old children was sensitive to changes in prereinforcement delay. These children showed a preference for the LL reward when the delay preceding it was 20 s, but this preference decreased as the delay increased, to the extent that when the LL reward followed a 50 s delay the children showed an almost exclusive preference for the SS reward. The results of the 4-year-old children were unclear, because 2 showed an increasing preference for the SS reward as the LL reward became more delayed, and 2 exhibited no consistent trend in preference. The children's verbal reports made following each session were also analysed. The verbal reports of the 12-year-old children were consistent with their behaviour and demonstrated an awareness of the economic rationale of choosing the SS reward when the LL prereinforcement delay was 50 s. In contrast, the verbal reports of the 4-year-old children were inconsistent with their behaviour; all expressed a preference for the LL reward even though they generally chose the SS reward. Sonuga-Barke et al. suggested that by 12-year-old, children had developed a sensitivity to delay that allowed effective economic assessment of reward conditions which younger children did not possess.

In a subsequent experiment, Sonuga-Barke et al. (1989c) conducted a similar experiment to Sonuga-Barke et al. (1989a), but using adult participants instead of children and points exchangeable for money instead of tokens. In addition to the manipulation of the prereinforcement delay between sessions (see Table 2-3), a context manipulation was also included. Three groups formed the context manipulation, a time constraint group, a trial constraint group, and a no information group. In the time constraint and no information conditions each session lasted 20 min while in the trial constraint condition each session lasted 25 trials. Thus, under the time constraint, to maximise reward it was necessary to change from the LL reward to the SS reward as the prereinforcement delay increased, but under the trial constraint it was always better to chose the LL reward. Participants in the time constraint group and the trial constraint group had the session constraint described to them prior to the start of the experiment, whereas those in the no information group were not supplied with any information regarding the time constraint. The results of this experiment showed that all three groups preferred the LL reward when the delay was 20 s. As the delay increased, this preference remained constant for the trial constraint condition, but those participants under the time constraint shifted their preference to the SS reward so as to maximise reward. Of those participants in the no information condition, 3 changed their preference to the SS reward as the LL delay increased but 1 consistently choose the LL reward and thus failed to maximise reward. In general, the participants' verbal reports accurately reflected the constraints under which they had chosen. Interestingly, the participant in the no information condition who failed to maximise described their performance as if they were choosing under a trial constraint. Sonuga-Barke et al. (1989c) replicated these findings in another experiment in which participants were rewarded with access to a computer game instead of points.

Together, the findings of Sonuga-Barke et al. (1989a, 1989c) so far discussed suggest that neither prereinforcement delay nor rate of reinforcement are unconditional determinants of human choice, and so cast doubt on any explanation of human behaviour based on temporal discounting. Instead, as discussed by Logue et al. (1986), the results seem to offer more support to the view that human performance under schedules is dependent on the generation and following of verbal rules. However, Sonuga-Barke et al. (1989c) pointed out that the findings discussed so far do not provided conclusive evidence against temporal discounting. To provide evidence that impulsiveness found in operant research results from miscalculation of reinforcement density as opposed to temporal discounting, Sonuga-Barke et al. (1989c) reasoned that it must be shown that a maladaptive preference for a SS reward must be shown by participants choosing under a time constraint. This was tested in a final experiment.

Sonuga-Barke et al.'s (1989c) final experiment used a concurrent-chain schedule with two terminal links, one that resulted in a SS reward and one that resulted in a LL reward. The SS reward consisted of a 0.5 s delay followed by 1 point and the LL reward consisted of a 15 s delay followed by 2 points. The initial link varied across conditions, and was dependent on either a VI 1 s schedule, a VI 8 s schedule, or a VI 20 s schedule. The number of points per minute produced by consistent choice of each reward are summaries in Table 2-4. When the initial link was comprised of a VI 1 s schedule, maximum reinforcement was produced by exclusive choice of the SS reward, but when the initial link was a VI 20 s schedule, maximum reinforcement was produced by exclusive choice of the LL reward. When the initial link was comprised of a VI 8 s schedule, both rewards offered identical density of reinforcement.

Table 2-4

Parameters of the two schedules used in Experiment 3, Sonuga-Barke et al. (1989c)

	Schedule parameters			
Initial Link	Pre-reward delay (s)	Reward size (points)	Reward delivery time (s)	Points per 60 s
Schedule 1 (SS)				
VI 1 s	0.5	1	6	8.00
VI 8 s	0.5	1	6	4.14
VI 20 s	0.5	1	6	2.26
Schedule 2 (LL)				
VI 1 s	15	2	6	5.45
VI 8 s	15	2	6	4.14
VI 20 s	15	2	6	2.92

Note. Points per 60 s = (60 / (VI + T + D)).

Twelve adult participants were divided into two groups. One group experienced the conditions outlined above under a time constraint (20 min) while the other experienced the conditions under a trial constraint (40 trials). Those participants in the trial constraint condition showed a preference for the LL reward under all three levels of the VI manipulation. However, participants in the time constraint condition showed a preference for the SS reward under all the three levels of the VI manipulation. When the initial link consisted of a VI 1 s schedule, choice of the SS reward was economically rational because it produced a greater reinforcement density than the LL reward. However, when the initial link consisted of a VI 20 s schedule, choice of the SS reward was a maladaptive. The findings thus offered convincing evidence for a miscalculation based account of laboratory observed impulsiveness in adult humans as oppose to temporal discounting.

2.3.4 Summary of Human Operant Research

In contrast to research using non-humans that have consistently shown impulsive behaviour, the results of those studies that have used human participants have been more difficult to interpret. The conventional view is that, like animals, humans discount delayed rewards and must therefore employ some form of commitment strategies in order to obtain the LL reward (Rachlin & Green, 1972; Solnick et al., 1980). However, of the studies covered in this review, those that have shown impulsive behaviour and evidence of temporal discounting have either involved children (Burns & Powers, 1975) or negative reinforcement with adults (Navarick, 1982; Solnick et al., 1980). When positive reinforcement has been used with adult participants, although a limited degree of impulsiveness was found by Millar and Navarick (1984), Logue et al. (1986) found that participants tended to maximise reinforcer amount regardless of reinforcer delay. Sonuga-Barke et al. (1989c) observed that under unequal rates of reinforcement and certain economic constraints (e.g., time restrictions or trial restrictions) choosing the LL reward does not always maximise the overall reinforcement. Under such condition, Sonuga-Barke et al. (1989a) found that some children preferred a LL reward even when this choice was grossly maladaptive and led to less reinforcement overall. This finding casts doubt on temporal discounting as a explanation of human behaviour, and Sonuga-Barke et al. (1989c) suggested that impulsiveness found in human operant studies may be the result of the participants "miscalculating" the reward rates of the alternatives.

2.7 Summary and Conclusions

For at least the last 25 years, the SS versus LL model of self-control has successfully dominated research into self-control and, unless an alternative can be proven to provide significant advantages, it will doubtless continue to do so for the foreseeable future. The empirical research it has generated has been successful at identifying factors that affect both humans' and animals' preferences for SS and LL rewards. Results from animal studies have shown that self-control behaviour is dependent on the delay and magnitude of the rewards in ways that can be predicted with quantifiable discount functions (e.g., Rachlin & Green, 1972). In addition, experiments have shown that non-humans will use an available commitment strategy to ensure they obtain the LL reward. In comparison, the findings of human studies are more ambiguous. Whereas there is strong evidence that temporal discounting explains impulsiveness in non-humans, the evidence derived from human studies is less convincing. Adult human participants typically show self-control under laboratory condition without the use of an overt commitment strategy. Logue et al. (1986) have suggested that human performance in self-control tasks may depend more on the generation and following of verbal rules that the actual contingencies of reinforcement.

However, despite the ever-increasing body of literature concerning choice under these conditions, the paradigm itself is not without criticism as a model of self-control.

Chapter Three - Self-control: An Alternative Approach

3.1 Criticisms of the Traditional Model

Recently, Rachlin (1995a) himself has argued that the traditional model, of which he was originally an advocate, fails to capture many of the essential characteristics of the situations to which the everyday language sense of self-control is usually applied. Rachlin identified two flaws in the traditional model. Firstly, it is argued that viewing self-control as a choice between two discrete rewards differing in delay and magnitude does not truly reflect many of the situations that are seen as involving self-control in everyday life. Whereas behaving impulsively does lead to a small reward that is available at a distinct point in time, as characterised in the traditional paradigm, Rachlin argues that in contrast there is no distinct point in time when the large reward resulting from the self-control response can be said to be received (cf. Ainslie, 1992; Ainslie & Gault, 1997). For example, although a pudding is a tangible reward for a person on a diet, achieving the desired weight and shape is not a discrete reward that occurs at a particular time like some giant dessert. Secondly, the rewards in the traditional SS versus LL model are mutually exclusive; choosing one precludes choosing the other. Rachlin argues that this is seldom true of the alternatives in self-control. Occasionally eating dessert has little effect on weight provided it does not happen too often.

3.2 Rachlin's Approach to Self-control

3.2.1 Acts and Patterns

To take account of the failings of the SS versus LL model, Rachlin (1995a, 1995b)[1] has proposed a novel approach that seems to better characterise many of the everyday situations that are seen as involving self-control. The pivotal difference between Rachlin's approach and the traditional model lies in the relationship between successive choices. In the traditional model, regardless of the number of choices that the participant is required to

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[1] Rachlin (1995b) offers a revised version of Rachlin's (1995a) theory which takes account of the peer commentary to the original article, particularly Kane (1995) and Kanekar (1995).

make, the distinction between self-control and impulsiveness can be made on each individual choice. In a single trial, if a pigeon chooses a 10 s access to grain after 6 s (LL) over a 1 s access after 2 s (SS) then by definition it has shown self-control. In contrast, within Rachlin's model, whether a choice is self-control or not cannot be determined from a single choice in isolation. Each choice must be considered in the wider context of those preceding it and those that are to follow.

Rachlin (1995a, 1995b) proposed that the relationship between behaviour and time be viewed in terms of *acts* and *patterns*. An act is defined as a relatively brief behaviour, as opposed to a pattern which is a relatively extended, repeated series of behaviours that are all associated with the same final goal. Consider the following behaviours:

1. pressing a key
2. typing a word
3. finishing a chapter
4. completing a thesis
5. becoming better educated

Within Rachlin's framework, each behaviour on the list can be seen as an act, but, at the same time it is also a pattern comprised of the acts inferior to it in the list. What changes between the levels of the list is the amount of context, or the length of the time frame that needs to be considered before the purpose of the behaviour becomes apparent to an observer. The further down the list, the wider context, or the longer the time frame needed to perceived the final cause of the behaviour. Rachlin notes that understanding a person's motive for behaving in a particular way, is perhaps better described as "outsight" than insight, a term previously used by Mahoney and Thoresen (1974). Outsight seems to better reflect the function of trying to understand a behaviour by perceiving it in the context of its wider implications, rather than looking inwards and trying to rationalise the person's state of mind. An individual may understand his own behaviour better than an observer, not because he has exclusive access to some private cognitive processes, but because he can perceive his own behaviour over a wider time frame or behavioural context. Although Rachlin acknowledges that some internal mechanism must be involved in this process, the contingencies forming a behavioural pattern may be characterised without reference to this process.

3.2.2 Self-control through Temporal Patterns

According to Rachlin's (1995a) theory, the value to an individual of a particular act is dependent on whether it is perceived in isolation or as a component within a wider pattern of behaviour. A breakfast of cereal, fruit and yogurt may have little value if perceived as an isolated event, but its value may be increased if it is perceived as part of a wider pattern of healthy eating. As the value of an act depends on its perceived relation to a pattern, so the value of a pattern may be greater or less than the sum value of its component acts. Rachlin (1995a) has liken a pattern to a symphony, where one wrong or missing note can ruin the whole piece of music for the listener, despite the fact that the incongruity is only one note out of thousands. On a less abstract level, one session of exercise will not result in physical fitness; only through regular sessions can fitness be achieved.

When a valued act is an element of a valued pattern — when we like what (we believe) is in our own long-term interests — then self-control is not an issue. For example, if an individual enjoys physical exercise then choosing to do exercise over lounging in front of the television does not seem to be an example of self-control, despite the fact that the individual values healthy living (a pattern) more than unhealthy living (another pattern). Only when we prefer an act that is an element in a less valued pattern is self-control relevant. If another individual, who hates physical exercise but likes watching television, chooses to exercise because she values healthy living then, by definition, she is exhibiting self-control.

Figure 3-1 illustrates Rachlin's (1995b) model of self-control. X and Y are acts, and components of patterns A and B respectively. X is worth less than Y if taken out of the context of its pattern. However, as part of pattern A, X is more highly valued than Y. Under these conditions, problems of self-control occur when a component of a lower valued pattern is worth more than the component of a more highly valued pattern. For example, a healthy diet (A) is generally more valued than an unhealthy diet (B). However, the components of an unhealthy diet (e.g. desserts and fatty foods) may be preferred to the alternatives offered by a healthy diet. Thus, self-control can be seen as behaving in ways that deliver relatively small immediate rewards but that contribute to a larger overall pattern of reward.

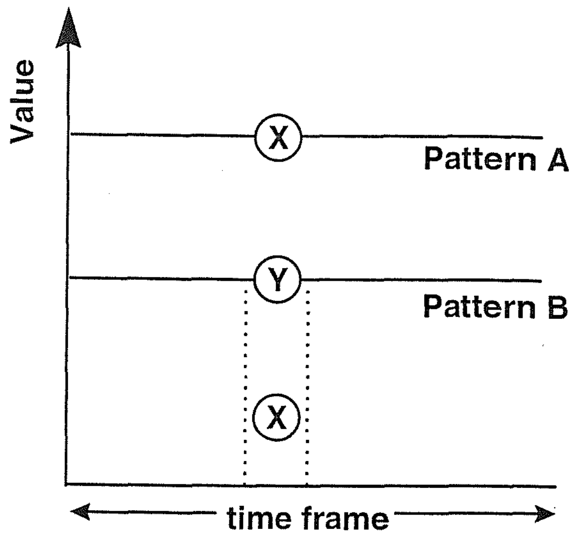

Figure 3-1. Illustration of Rachlin's (1995b) analysis of a self-control situation. Self-control problems occurs when an act of a lower valued pattern of behaviour is worth more that an act of a greater valued pattern. Act X is a component of Pattern A and Act Y is a component of Pattern B. As part of a wider pattern of behaviour X is worth more than Y. However, if compared out of context, Y has the greater immediate value.

Under Rachlin's (1995a, 1995b) model, both impulsive and self-control behaviours result in an organism maximising reward, but the distinction lies in the time scales involved. The impulsive choice maximises the relatively immediate (local) reward but at the expense of the greater, overall (global) reward that is obtained through self-control.

Rachlin (1995a) proposed that self-control is developed by restructuring behaviour into wider patterns, such that immediately less valuable acts are enhanced by their perceived, more desirable, global consequences. Instead of the need for an overt commitment strategy (i.e., physical restraint), commitment to a desired pattern (self-control) is maintained because a cost is associated with interrupting a pattern once begun, a cost that increases the longer a pattern continues. Returning to the symphony analogy, one wrong note devalues the whole piece. However, whereas a pattern is abstract and distributed over a wide period of time, an interruption is a particular event that occurs at a particular time. Thus, in a self-control choice, the cost of interrupting a highly valued pattern can directly oppose and devalue an alternative act. Essentially it is Rachlin's contention that self-control does not involve a choice between an SS reward and a LL reward, but rather it involves a choice between two concurrently available rewards that change their values depending on the context they are perceived in.

Although Rachlin (1995a) acknowledges that "This process [of restructuring of behaviour] of course requires the operation of the nervous system, presumably its higher functional levels. The defining attributes of self-control, however, may be found not within the nervous system but at its borderline with the environment — in the behavior of an intact organism (p.117)", his analysis provides a behavioural explanation of self-control that does not have to resort to fictional constructs, such as internalised commitment.

3.2.3 Empirical Research

Rachlin (1995a) offered several studies in support of his local versus global approach to self-control. The first, Siegel & Rachlin (1995), examined the behaviour of pigeons in a variation of the more traditional SS versus LL design. Two other studies, Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996) also investigated the behaviour of human participants in a novel choice paradigm that directly opposed local and global rewards.

In the experiment reported by Siegel and Rachlin (1995), four pigeons, at 80% of their free-feeding weights, were repeatedly exposed to a choice between a SS reward (a 0.5 s delay followed by 2.5 s of grain access) and a LL reward (3.5 s delay followed by 4.5 s of grain access). The postreinforcement delay was controlled so that maximum reward was obtained by consistently selecting the LL option. A baseline condition provided reward on a single key-peck and, as found in previous studies (e.g., Rachlin & Green, 1972), the birds showed a strong preference for the SS reward. However, when the schedule was changed to a fixed-ratio 31 (FR31), with the 31st peck determining reward and the preceding 30 pecks potentially on either key, the birds' preferences changed significantly. Once a bird began pecking the key that led to the LL reward there was a strong tendency to persist until rewarded. In fact only one pigeon on one occasion switched to the SS key on the 31st peck after 30 successive pecks on the LL key. Rachlin (1995b) argued that this finding provided evidence of the restructuring of behaviour into wider patterns that leads to self-control, and that it was the cost associated with defecting from the pattern that allowed the pigeons to obtain the LL reward. However, what Rachlin fails to explain is what the cost of defection actually is. The birds could have made any pattern of key pecks during their first 30 responses without apparent loss, and explaining why they tended to respond consistently on the key that would eventually deliver the LL reward because of some undefined cost seems unsatisfactory. Also, Fantino (1995) has questioned whether it is time or the number of responses that is the important variable; would 30 pecks over 30 s be anymore effective than 30 pecks over 15 s? This question has not yet been answered.

The two human studies (Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996) employed a choice procedure devised by Herrnstein, Prelec and Vaughan (see Herrnstein & Prelec, 1992; Herrnstein et al., 1993). The procedure, that will henceforth be referred to as the Herrnstein procedure, was designed to simulate choice situations in which current consumption affects future rewards. A particular version of this procedure captures the relationship between acts and patterns (Rachlin, 1995b). The basic procedure requires the participant to make successive choices between two concurrently available schedules of reward. Choice of the immediately larger reward reduces the value of both rewards on subsequent trials. Conversely, choice of the immediately smaller reward raises the value of both rewards on subsequent trials. Therefore, although choice of the larger reward maximises local reward, on a trial for trial basis, maximum global reward is achieved by repeatedly choosing the smaller of the two immediate alternatives. In these terms, self-control can be seen as acting in ways that deliver relative small immediate rewards but that contribute to a greater overall pattern of reward.

Given that maximisation is an organism's fundamental goal (cf. Rachlin, Battalio, Kagel, & Green, 1981; Kacelnik & Krebs, 1997), Herrnstein et al. (1993) have classified the reasons why behaviour might deviate from global maximisation into two broad classes, the *cognitive* and the *motivational*. Cognitive reasons concern the individual's awareness of the global contingency; that is that their current choices have implications for the consequences available to them in the future. For example, most smokers are aware that smoking can cause serious health problems in later life. Such awareness could either develop from first-hand experience of the contingencies or, more likely, be gained through another person's verbal descriptions (see Hayes, 1989). Although Herrnstein et al. meant awareness to imply explicit knowledge of a situation, it is important to note that awareness could conceivably mean implicit knowledge as well (Berry & Dienes, 1993). According to Herrnstein et al. (1993), awareness is necessary but not sufficient for a person to maximise global rewards. This is exemplified in the example of smoking; smokers smoke despite being explicitly aware of the health risks. Situations often occur where a person behaves for immediate gain despite "knowing" that it is not in their long-term interests. In such cases, the failure to maximise globally is usually explained in terms of motivational factors, the most common of which is temporal discounting, discussed in chapter 1 (see Prelec and Herrnstein, 1991, for a discussion of other potential factors).

Empirically, Herrnstein et al. (1993) approached the question of global maximisation through a series of experiments in which participants interacted with a computer program that required them to repeatedly choose between two interdependent schedules of reward that generated local and global alternatives. All the experiments followed that same basic format. Two coin hoppers, A and B, were displayed at the top of the computer screen and on each trial the participant had to select which hopper they wished to collect from by pressing one of two keys. When a key was pressed a graphic of a coin dropped from the hopper into a collector at the bottom of the screen. Depending on the particular study, either the value of the coin or the rate of reinforcer delivery was dependent on the previous choice(s) that the participant made. The factors investigated were reportedly chosen because intuitively they should have affected the participants' perception of the wider-temporal contingencies, thus promoting or reducing the likelihood of global maximisation.

In the first two experiments, the participants experienced 400 trials in which they were required to choose between two different outcomes, the monetary values of which were displayed on the coin hoppers. The value of the coins available on any trial was a function of the proportion of A responses made during a constant number of previous trials, depending on the condition. Herrnstein et al. (1993) referred to this number of previous trials as the *averaging window*. The relationship between coin value and the proportion of previous choices was a curvilinear function, such that participants maximised global reward by making a certain proportion of responses on each key during the average window. As an example, the reward functions used in experiment 1 are shown in Figure 3-2. The value of an A response is relatively small but it increases gradually the more that it is chosen. In comparison, the value of a B response is relatively large, but only if it is chosen infrequently. If the B response is chosen frequently then its value rapidly declines, and it can fall below the value of an A response. Global maximisation occurs when a proportion of .86 of the responses within the averaging window are A responses. Herrnstein et al. proposed that such functions may reflect situations in which a consumer may become satiated by a commodity, so that global maximisation is achieve by at least occasionally choosing an alternative. For example, the reward functions illustrated in Figure 3-2 could reflect the pay-offs for a fisherman who has a choice between two different size nets everyday, one large (A) and one small (B). If the fisherman uses the large net then he will catch more fish than if he used the small net. Nevertheless, if he uses the large net too frequently then the overfishing decreases the stock and he will eventually catch very few fish. If the fisherman uses the small net then he will catch fewer fish than if he used the large net, but the amount he catches gradually increases because the fish stocks are allowed to grow. However, the system can tolerate the occasional use of the large net without overly damaging the fish stocks. Thus, the fisherman can maximise the amount of fish that he catches by generally using the small net and only occasionally using the large net.

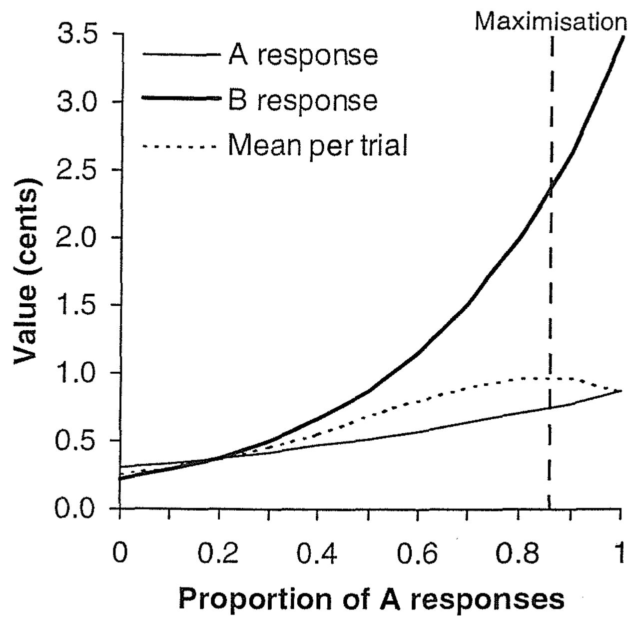

Figure 3-2. Reward functions used in Herrnstein et al. (1993), experiment 1. Monetary reward (cents) resulting from an A or a B response as a function of the proportion of A responses in the averaging window. The mean line indicates the weighted average outcome per trial as a function of the proportion of A responses. Global maximisation occurs at a proportion of .86 A responses.

Rachlin (1995a) only discussed his act versus pattern model in terms of linear reward functions, that will be introduced below, and did not commented on the place that curvilinear relationships may play in self-control. Whether this omission indicates that Rachlin dismissed the importance of curvilinear functions, or whether this neglect was simply a matter of succinctly presenting a new theory, is unclear. However, Herrnstein et al.'s (1993) first two studies will be discussed brief because the factors examined are likely to be relevant to self-control and they form the basis for the subsequent experiments that used linear functions.

In Herrnstein et al.'s (1993) experiment 1, the main independent variable was the length of the averaging window. This was tested using a between-subjects design and was either 6 or 20 trials. The results showed that when the averaging window was 6 trials long, participants made a significantly greater proportion of global choices and there was less intersubject variability compared to when the averaging window of 20 trials. In experiment 2, the averaging window, again either 6 or 20 trials, was studied both between-subjects and within-subjects across two sessions. In the first session, half the participants chose under an averaging window of 6 trials and the other half chose under an averaging window of 20 trials. In the second session the conditions were reversed. As in experiment 1, during the first session, those participants who experienced the smaller averaging window were closer to global maximisation. However, the results showed an interaction between averaging window and session. Those participants who experienced an averaging window of 6 trials first and 20 trials second showed no change in performance between sessions. In contrast, those who experience an averaging window of 20 trials first showed a significant shift towards maximisation when the averaging window was reduced to 6 trials in the second session, to a level comparable with the other group. Herrnstein et al. argued that a smaller averaging window allowed cognitive factors to operate more effectively, thus favouring global maximisation. Increasing the size of averaging window made the global contingency less salient by making the changes between trials more gradual, a fact that Herrnstein et al. suggested caused the participants to pay it less attention.

Herrnstein et al. (1993) observed that the participants in experiments 1 and 2 performed better in terms of global maximisation in contrast to previous unpublished studies. The design of these unpublished studies reportedly differed in two respects. First, the reward functions of the two schedules were linear and parallel as opposed to curvilinear and intersecting. For comparison, examples of curvilinear and linear reward functions are shown in Figure 3-3. With the curvilinear functions the differential between the values of the two alternative choices on any trial varied according to the proportion of previous responses made within the averaging window, and global maximisation is achieved by allocating responses between the two choices at particular proportions. For example, in experiment 1, global maximisation was achieved by proportions of .86 A responses and .14 B responses. With the parallel functions there was a constant differential between the values of the two alternative choices, and global reward is maximised by exclusively choosing the schedule that delivered the immediately poorer alternative. It is these parallel functions that Rachlin (1995a) used to exemplify his model of self-control.

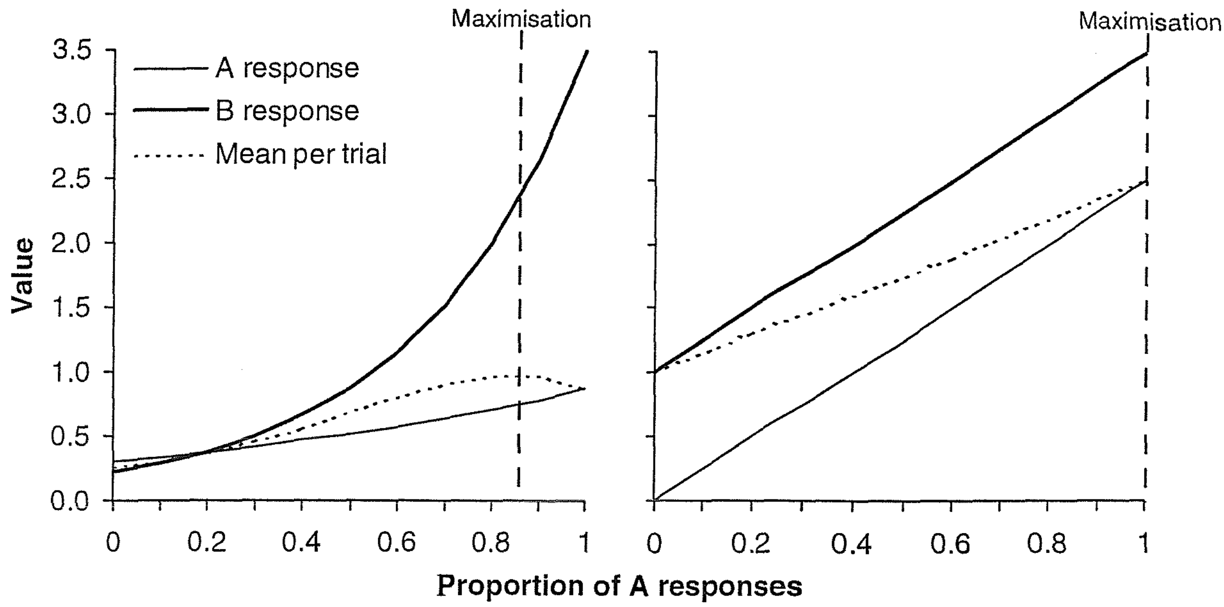

Figure 3-3. Comparison of curvilinear reward functions (left) and linear reward functions (right). For both graphs, the value of an A or a B response is a function of the proportion of A responses in the averaging window. The mean line indicates the weighted average outcome per trial as a function of the proportion of A responses. With the curvilinear functions, global maximisation occurs at a proportion of .86 A responses. With the linear functions, global maximisation occurs at a proportion of 1.0 A responses.

The second reported difference between Herrnstein et al.'s (1993) published and unpublished experiments was the reward dimension under the participants' control. In the unpublished studies the reward dimension was the delay preceding a fixed magnitude reward rather than the actual magnitude of the rewards themselves. With the delay design the participants chose under a time constraint, as opposed to a trial constraint, so that global maximisation was achieved by minimising the average delay per trial.

Experiment 3 reported by Herrnstein et al. (1993), attempted to directly compare curvilinear and linear functions, and coin delay and coin value. Participants experienced two sessions making their choices under linear reward functions and two sessions making their choices under curvilinear functions, counterbalanced to control for possible order effects. The reward dimensions, coin delay and coin value, were tested on separate groups of participants. The results of this experiment showed that when the reward functions were intersecting, participants in both the coin delay and coin value conditions had a tendency to distribute their responses approximately equally between the two alternatives. This finding was consistent over the two sessions. In comparison, the analysis revealed a significant main effect of reward dimension when the reward functions were parallel. The mean proportion of global responses under the conditions with parallel reward functions are shown in Table 3-1. Those participants who were exposed to the coin value procedure made a significantly greater proportion of global responses than those in the coin delay condition.

Table 3-1

Herrnstein et al. (1993) Experiment 3: Mean proportions of global responses in the latter half of each session for coin delay and coin value under parallel reward functions

	Proportion of Global Responses	
	Session 1	Session 2
Coin Delay		
M	.17	.27
SD	.26	.35
Coin Value		
M	.75	.63
SD	.26	.28

In the first three experiments reported by Herrnstein et al. (1993), the factors examined were, by their definition, cognitive; factors that affected the participants awareness of the global contingency. The aim of Herrnstein et al.'s fourth experiment was to assess the impact of a motivational factor on participants' responses. In experiment 3, those participants in the coin delay condition had to choose the immediately longer delay on each trial in order to maximise the global reward. Herrnstein et al. speculated whether participants made a greater proportion of local responses, not because they were unaware of the global contingency, but because they were too "impatient" and found the immediately longer delay more aversive than the shorter alternative, even though choosing the immediately longer delay resulted in a smaller average delay overall. In other words, participants may have failed to globally maximise because a sooner reward was valued more than a delayed reward, even though it led to less reward overall. To test this possibility, Herrnstein et al. cleverly manipulated the context under which the participants made their responses while keeping the actual physical conditions of the procedure constant. The experiment employed a coin delay procedure but the context was framed in terms of either earning or losing money. This offered a test of the impatience hypothesis because impatience favoured maximisation when losing money (i.e., losing the least money), but opposed maximisation when gaining money.

The procedure, as previously described, involved two coins hoppers (A and B) that delivered their rewards when the appropriate key was pressed. Each session consisted of a 300 s warm-up period and 900 s experimental period in which coins were either earned or lost. After a choice was made, the delay preceding the next choice-point was marked graphically by a coin falling from the appropriate hopper into a collector at the bottom of the screen. The length of this delay period was calculated according to the following rules:

1. Each choice of A produced a delay of $(N + 2)$ s.
2. Each choice of B produced a delay of $(N + 4)$ s.
3. N was equal to 4 divided by the proportion of A choices in either the preceding 3 or 10 trials, depending on the condition.

The linear reward functions generated by these rules are shown in Figure 3-4. Each A response always delivered the immediately shorter delay but increased both delays on subsequent trials. Repeatedly choosing A led to the maximum average delay (6 s) per trial, and therefore, the least coins earned and lost. Each B response always delivered the immediately longer delay but decreased both delays on subsequent trails. Repeated choosing B led to the minimum average delay (4 s) per trial, and therefore, the most coins earned and lost.

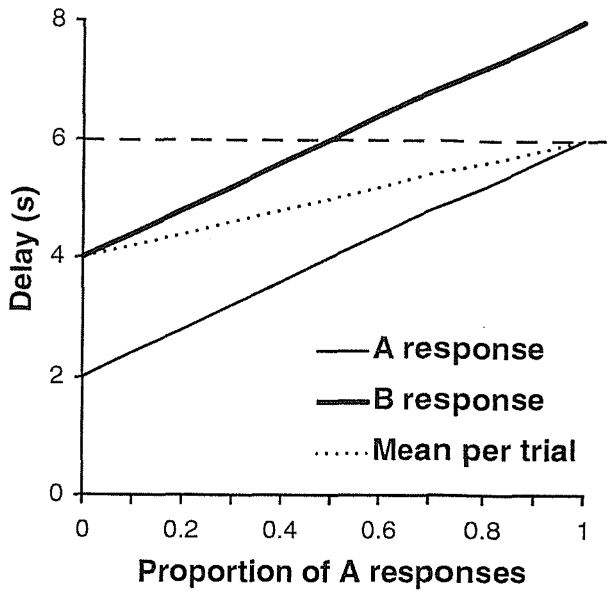

Figure 3-4. Reward functions used in Herrnstein et al. (1993), experiment 4. Delay preceding reward resulting from an A or a B response as a function of the proportion of A responses in the averaging window. The mean line indicates the weighted average outcome per trial as a function of the proportion of A responses. The dashed line at 6 on the y-axis is provided for visual clarity.

The earning or losing context of the choice procedure was manipulated within-subjects, and the order was counterbalanced across two sessions. Each participant received a basic payment of $5.00, that was then modified by their performance. In the earning condition, the participants were told that the value of the coins accumulated over the session would be added to their basic payment. In the losing condition, the participants were told that the value of coins accumulated over the session would be deducted from their basic payment. In addition to the context manipulation, the averaging window was varied between subjects, and was either 3 or 10 trials.

If, as Herrnstein et al. (1993) suggested, the participants found the immediately longer delay more aversive then, regardless of the earning or losing context, this should have be shown in a greater proportion of global responses under the coin loss condition than the earning condition. The results of this experiment are shown in Table 3-2. Although analysis showed the coin loss condition produced a slightly greater proportion of global responses, this was only marginally significant (p = .07). Herrnstein et al. interpreted this finding as meaning that delay did have a weak motivational effect on choice preference, causing the participants to chose the immediately better alternative despite the detrimental effect on the overall pattern of reward.

Table 3-2

Herrnstein et al. (1993) Experiment 4: Mean proportions of global responses in the latter half of each session for coin gain and loss under averaging windows of 3 and 10 trials

		Proportion of Global Responses	
Condition		Session 1	Session 2
Window size 3			
Gain	*M*	.51	.57
	SD	.36	.37
Loss	*M*	.61	.62
	SD	.26	.41
Window size 10			
Gain	*M*	.14	.17
	SD	.17	.26
Loss	*M*	.39	.13
	SD	.40	.17

In summary, the first four studies reported by Herrnstein et al. (1993) showed that participants had a general tendency to respond for local as opposed to global reward. Herrnstein et al. concluded that this failure to maximise the global reward was due to the participants' insensitivity to the contingencies of global choice. In other words, the participants were simply unaware that to maximise the global reward they had to choose the immediately worse alternative each time. In the fifth and final study, Herrnstein et al. tested this assumption by offering participants varying degrees of hints regarding the optimal choice strategy. The condition used in the experiment was the same as the experiment 4 condition, choosing under the coin earning context and with an averaging window of 10 trials. Three groups of subjects participated. One group received no additional information, one group received a 'medium-hint' and the other group receive a 'strong-hint'. Participants in the medium-hint condition were told that repeatedly responding on one schedule increased the value of both on subsequent trials and repeatedly responding on the other decreased the value of both on subsequent trials. Participants in the strong-hint condition were specifically told which schedule produced which effect.

As predicted, analysis of the results showed that the participants provided with a strong-hint were closest to maximising global reward (mean proportion of global responses = .60, standard deviation not supplied), followed by the medium-hint group ($M = .27$), and the no-hint group last ($M = .14$). However, there was a high degree of variability within the groups, and even in the strong-hint group few participants exclusively chose the schedule resulting in global maximisation. In addition to collecting information of the proportion of responses made, verbal protocols were collected from the participants at the end of the session regarding their understanding of the rules. Analysis of the protocols suggested that being able to verbalise the optimal strategy did not guarantee optimal performance. However, those participants who were farthest from maximising did express rules based on maximising local reward (i.e., choosing the shortest delay per trial), and those closest to maximising typically expressed rules suggesting awareness of the global pattern of reward.

Following on from the pioneering research performed by Herrnstein et al. (1993), the Herrnstein procedure has been adopted and adapted by other researchers who have investigated the conditions under which humans successfully maximise global reward. Because patterning, the grouping of trials together into discrete units, was found to facilitate self-control in pigeons (Siegel & Rachlin, 1995), Kudadjie-Gyamfi and Rachlin (1996) investigated whether patterning would similarly affect human behaviour in the Herrnstein procedure. The experimental conditions were presented to participants through a computer, attached to which was a box with two identical buttons (A and B) on the top. The participants were instructed that they had a pool of 325 s during which, until the time was exhausted, they could score points, and that at the end of the experiment they would be paid 10 cents (7 pence) for each point they had scored. Responses were made through the buttons on the box and resulted in 1 point being added to a cumulative total displayed on the screen followed by a delay, that was deducted from the pool, before the next response would be accepted. The delay imposed per choice was calculated according to the following rules:

1. Each choice of A produced a delay of N s.
2. Each choice of B produced a delay of $(N + 3)$ s.
3. N was equal to the number of A responses made during the preceding 10 trials.

The reward function generated by these rules are shown in Figure 3-5. These rules provided maximum financial reward for repeatedly choosing B that, although it produced a worse (longer delay) alternative on any individual trial, minimised the average delay over the entire session. Minimising the average delay maximised the number of trials before the 325 s were expended and, therefore, maximised the participant's financial return.

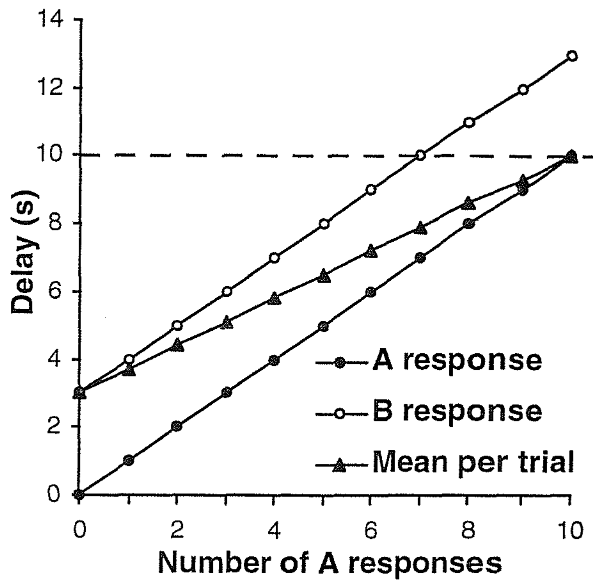

Figure 3-5. Reward Functions used in the experiment by Kudadjie-Gyamfi and Rachlin (1996). Delay preceding reward resulting from an A or a B response as a function of the number of A responses in averaging window (the preceding 10 trials). The mean line indicates the weighted average outcome per trial as a function of the average number of A responses within the averaging window. The dashed line at 10 on the y-axis is provided for visual clarity.

Participants were randomly assigned to one of four experimental groups, that differed in the arrangement of inter-trial intervals (ITI). During an ITI the computer was unresponsive, but no time was deducted from the pool. Group 1 experienced a group of three successive choices-outcomes (CO) pairings followed by an ITI of 30 s. Groups 2 and 3 experienced just a single CO followed by an ITI of 10 and 30 s, respectively. Group 4 experienced uninterrupted COs with no ITIs. Groups 2, 3, and 4 acted as controls because together they experiencing the same rate of trial presentation as Group 1. These conditions are summarised in Table 3-3.

Table 3-3

Kudadjie-Gyamfi and Rachlin's (1996) experimental design

Group	Design	Chain length	Inter-trial interval
1	COCOCO	Triplet	30 s
2	CO	Single	10 s (same overall rate of Group 1)
3	CO	Single	30 s (same absolute rate as Group 1)
4	CO	Single	0 s (same local rate as Group)

Participants had a general tendency to choose the immediately quicker reward (A), and thus failed to maximise the financial reward. However, this effect was modified by trial grouping. Compared to the controls, those participants who were forced to make their responses in groups of three, each followed by an ITI of 30 s, made a significantly higher proportion of global (B) responses than the other three groups. The average number of trials made by this group was 58, compared to the highest of the other groups (0 s ITI) which was 42. Rachlin (1995b) has argued that grouping choices together had this effect because it emphasised the global pattern of reward associated with repeated choices. Alternatively, it is conceivable that the inter-trial delays may have affected the participants' judgements of post-reward delays, and that the advantage provided by trial grouping was that it made the changes in the post-reward delays easier to discriminate rather than emphasising the benefits of repeated choices. An addition study in which the participants were not required to be sensitive to changes in delay (e.g., one that uses points as the reward dimension) would be necessary to identify which of these two reasons explains why grouping favours global maximisation.

Kudadjie-Gyamfi and Rachlin's (1996) second experiment was designed to replicate Herrnstein et al.'s (1993) finding that presenting participants with explicit verbal information regarding the global contingency improved global performance. The experimental design resembled the conditions experienced by Group 4 in their first study, differing only in the instructions provided. Half the participants received the standard instructions (no hint) while half received the standard instructions plus a short passage explaining how current choices affected the future rate of reward (hint). However, in contrast to Herrnstein et al.'s (1993) results, the analysis showed no significant difference between the choices made by these two groups.

Since Rachlin's (1995b) article, several more studies exploring factors affecting local versus global choice have been reported. For example, Sokolowski (1996; 1998) has reported a series of studies that have attempted to compare the responses made by pigeons and humans under equivalent conditions. In an innovative design, during each 40 s trial, subjects were given the opportunity to work for a fixed reward. Humans received approximately 4 pence while food-deprived pigeons received a 3.5 s access to grain. To receive the reward humans had to operate a heavy lever (1.25 kg per response) and pigeons had to peck a response key. However, the amount of work the subject had to do to receive the reward, that is, the number of responses the subject needed to make, was dependent on which of two ratio schedules (A or B) the subject selected. At the beginning of each trial the subject selected a schedule by pressing (or pecking) one of two buttons. Each schedule delivered reward according to the following rules:

1. Schedule A delivered reward after N responses.
2. Schedule B delivered reward after $(N + 10)$ responses.
3. N was equal to the number of A choices made during the preceding 10 trials multiplied by 2.

The reward functions generated by these rules are shown in Figure 3-6. These rules meant that, on any given trial, choosing A resulted in the least work to gain the reward on the current trial, but increased the work required on subsequent trials. In comparison, although choosing B meant more immediate work to gain the reward it reduced the work required on subsequent trials. Thus, the minimum average work to receive reward was achieved by repeatedly choosing the more effortful of the two immediate alternatives, B.

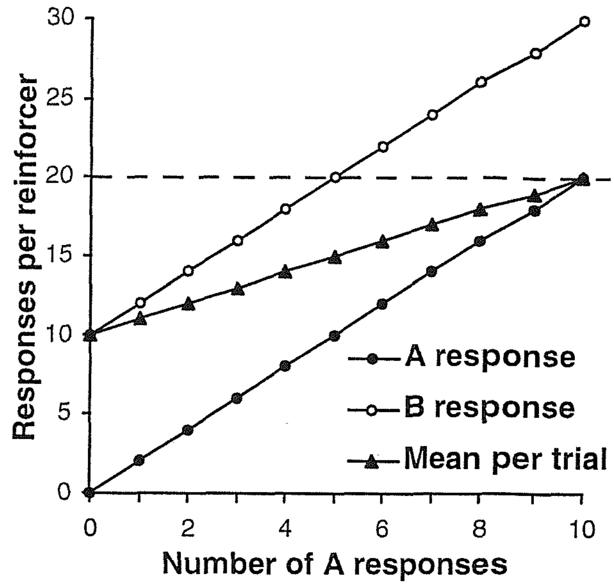

Figure 3-6. Reward functions used in Sokolowski (1996). Responses per reinforcer resulting from an A or a B response as a function of the number of A responses in averaging window (the preceding 10 trials). The mean line indicates the weighted average outcome per trial as a function of the average number of A responses within the averaging window. The dashed line at 20 on the y-axis is provided for visual clarity.

Sokolowski (1996) repeatedly tested 3 pigeons and 4 humans over a number of experimental sessions. A session consisted of 60 and 90 trials for pigeons and humans respectively. The most striking finding was the clear difference in performance between species. The pigeons showed a strong preference for local reward, minimising the amount of work per trial despite the fact that this pattern of choice resulted in a greater average work per trial. In comparison, after a completing a few sessions, 3 out of the 4 human participants almost exclusively chose the global reward, minimising the average work per trial. The fourth human participant showed an almost exclusive preference for the local reward even though they were choosing under identical conditions. Sokolowski was fairly circumspect in explaining the apparent difference in the behaviour of pigeons and humans and also failed to comment on why his study was so successful at producing global maximisation in human participants compared to Herrnstein et al. (1993). One possible explanation could be that human are more sensitive to global changes in workload than they are to changes in either points or delay. Such an explanation would certainly seem to make ecological and evolutionary sense. However, it is also possible that Sokolowski's findings may simply be the result of prolonged exposure to the contingencies. Participants in Herrnstein et al.'s longest study, experiment 1, experienced a total of 550 trials while participants in Sokolowski's experiment experienced between 720 and 900 trials (8 to 10 sessions).

Finally, Gray (1999) has examined the effect of negative emotional states on local versus global choice preference. After reviewing the literature, Gray concluded that it was adaptive for an organism to respond for the immediate benefit in situations of danger, regardless of any detrimental long-term consequences. Logue (1995b), discussed in chapter 1, has made a similar point in explaining why animals have a tendency to behave impulsively. To test the prediction that negative emotional states correlate with a preference for local reward, Gray exposed participants to an experimental picture slide-show in which the length of exposure to each image was determined by a variant of the Herrnstein procedure. The stimuli were presented on a computer, attached to which was a keyboard with two keys, labelled A and B, that the participant could press to change the picture. Participants were paid 4 cents each time they changed the picture during a 10 min session. Each trial, shown schematically in Figure 3-7, a picture was presented on the screen and a fixation point (a plus sign, '+') was superimposed over the image. The time the fixation point remained on the screen was determined by the participant's previous choices, and only when the fixation point disappeared could the participant advance to the next image by pressing one of the two marked keys. Thus, the participant was forced to attend to each image.

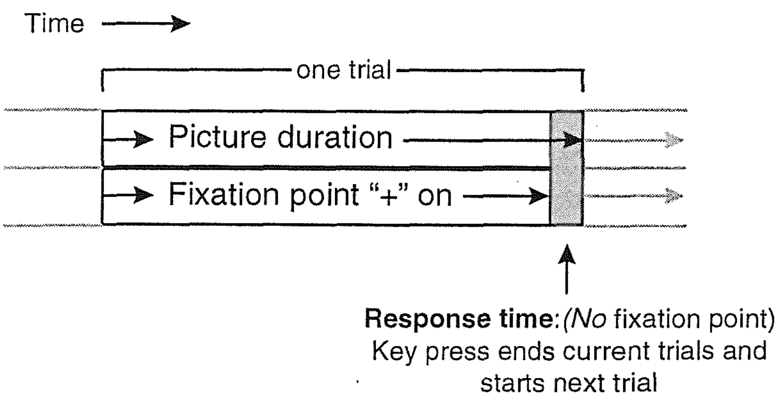

Figure 3-7. Schematic diagram of a trial in Gray (1999). The duration of a trial, during which a picture was displayed, consisted of the duration of the fixation point plus the response time between the disappearance of the fixation point and the participant's key-press. Following the key-press, the next trial began immediately.

Unlike other studies using the Herrnstein procedure, there was no difference between the two alternatives on the current trial. When either button was pressed the next trial began immediately. Only on the following trial(s), did the current choice have an impact. The duration of the fixation point, after which the participant's key-press would change the picture, varied between 3 and 7 s and was dependent of the 4 preceding trials according to the following rules, the effects of which are summarised in Table 3-4.

1. The minimum duration of the fixation point was 3 s.
2. Choosing A decreased the fixation point duration on the next trial by 1 s, but increased the duration on the subsequent 3 trials by 1 s.
3. Choosing B increased the fixation point duration on the next trial by 1 s, but decreased the duration on the subsequent 3 trials by 1 s.

Overall, each A response increased the overall fixation point duration by 2 s and each B response decreased the fixation point duration by 2 s. The minimum average picture duration, and therefore maximum monetary gain, was therefore obtained by repeatedly choosing B.

Table 3-4

Summary of the effects on the following 4 trials of an A and a B response on trial n, from Gray (1999)

	Change in fixation point duration on trial (s)				
Response	n + 1	n + 2	n + 3	n + 4	Net change (s)
A	-1	+1	+1	+1	+2
B	+1	-1	-1	-1	-2

The pictures that Gray (1999) used in his experiment were drawn from the International Affective Picture System (Lang, Greenwald, & Bradley, 1990). To induce a negative emotional state, the experimental group were exposed to a cycle of 10 aversive, threat-related images (e.g., a mutilated hand). Those in the control group were exposed to 10 neutral images (e.g., a man with beard). Gray's (1999) analysis of the results supported the hypothesis. Those participants exposed to the threat-related images showed a significant preference for the local reward, earning a mean of $1.54, as compared to the control group, who earned a mean of $1.69. Gray alluded to the possible existence of visual and visuallybased motivational factors resulting from the use of aversive pictures that may have confounded the results within the his initial design. To avoid these confounds, a second study compared participants who self-reported stress due to impending exams with participants who reported little or no current stress. As the negative emotional state, stress, was independent from the study, only neutral pictures were used in the experiment. The results were comparable to the original study. Those participants in the high-stress group showed a greater tendency for local reward, earning a mean of $1.51, as compared to the low-stress group, who earned a mean of $1.68.

3.2.4 Evaluations of Rachlin's Model

Rachlin's (1995a) article was simultaneously published with commentaries by both psychologists and philosophers interested with the problem of self-control. Despite highlighting some potential weaknesses and points of contention, the majority of the commentators found something of value within Rachlin's theory. Many agreed that conceiving of behaviour in terms of local and global rewards better characterises many situations that are seen as self-control (Baum, 1995a; Baumeister, 1995; Green & Myerson, 1995; Hocutt, 1995; Plaud, 1995; Shimoff, 1995). However, some researchers rejected Rachlin's criticism and maintained that the established SS versus LL approach remained appropriate (Ainslie & Gault, 1997; Killeen, 1995; Logue, 1995a). The main point of contention for these theorists revolved arrange the nature of the reward resulting from a self-control response. Logue (1995a) and Ainslie and Gault (1997) both accept the idea of temporally extended patterns of behaviour, but reject the assertion that such patterns do not result in a discrete, LL reward. The general argument is that, despite a pattern being a complex series of interconnected behaviours over a wide period of time, the value of that pattern can still be assessed by the individual at any given point in time. Therefore, despite involving successive choices, self-control is still essentially a choice between a SS and a LL reward (Ainslie, 1992).

Many of the evaluations of Rachlin's theory reflect the same fundamental differences in opinion that surround the more traditional approach, specifically whether the factors controlling behaviour are internal (attention: Baumeister, 1995; emotions: Frank, 1995; cognitive representations: Lemm, Shoda, & Mischel, 1995; Mosterin, 1995) or external (rule-governed: Baum, 1995a; Branch, 1995; Eisenberger, 1995; Overskeid, 1995). The two aspects that are questioned repeatedly in the commentaries are how patterns initially develop and how, once established, the pattern maintains the self-control behaviour (e.g., Zentall, 1995).

Rachlin has said little about how behaviour is restructured into wider patterns, although he has alluded to the possible importance of verbal rules to the development and maintenance of such patterns (Rachlin, 1997). After all, rules need not identify specific LL consequences, and could characterise the global benefits (the non-direct acting contingency; Malott, 1989) of self-control. For example, "healthier", "happier", and "more relaxed" are everyday descriptions of personal states that most people would probably say that they strove for. So, Rachlin's paradigm is easily managed in terms of rule-governed behaviour. As to explaining why a pattern maintains itself, Rachlin says that it is because a pattern has an intrinsic value that is lost if the pattern is disrupted. However, several theorists have criticised Rachlin's theory for being too vague concerning why patterns have intrinsic value and failing to specify the exact nature of the costs which result from defection (Ainslie & Gault, 1997; Baum, 1995a; Hineline, 1995; Shimoff, 1995; Silverstein, 1995; Zentall, 1995). Rachlin (1995b) concedes that these definitions are as yet ill-defined, but asserts that the logic of cost is necessary within the proposed theory.

3.3 Summary

Rachlin (1995a) has criticised the prevailing SS versus LL model of self-control on the grounds that it poorly reflects those situations to which the everyday sense use of self-control is usually applied. To account for these weaknesses, Rachlin has proposed a novel theory in which self-control can be seen as acting in ways that deliver relatively small immediate (local) rewards but that contribute to a greater overall (global) pattern of reward. Rachlin proposed that self-control is developed by restructuring behaviour into wider patterns of behaviour because patterns are costly to interrupt once begun and that it is this cost that opposes the value of any alternative, impulsive behaviour. A choice procedure devised by Herrnstein, Prelec and Vaughan (Herrnstein et al. 1993) captures the characteristics of Rachlin's (1995a) theory, allowing its operation to be studied in the laboratory.

3.4 The Present Thesis

The present thesis was originally conceived as an general assessment of Rachlin's (1995a) theory as a possible successor for the traditional SS versus LL model of self-control. However, as the thesis developed the focus has centred more specifically on Rachlin's structural analysis of the self-control situation, that can be explored empirically using the human choice procedure devised by Richard Herrnstein, Drazen Prelec and William Vaughan, Jr. (see Herrnstein & Prelec, 1992; Herrnstein et al., 1993). The four experiments contained in this thesis, described in chapters 5 to 8, examined the affect of several factors on the choice responding of human participants in the laboratory with the aim to relate the findings to Rachlin's model of self-control.

Chapter Four - Methodological Considerations

4.1 Introduction

The aim of this chapter is to describe in detail the form and characteristics of the Herrnstein procedure (Herrnstein et al., 1993), and to outline the development of the software that was used in the four experiments, reported in chapters 5 to 8.

In the basic procedure a participant is required to repeatedly choose between two concurrently available schedules of reward. However, whereas in many choice procedures the schedules operate independently (see Mazur, 1991, for review), one of the defining characteristics of this paradigm is that the current returns of both schedules are dependent on the pattern of responses made in the preceding trials. This interaction between previous choices and current returns is commonly referred to as an *internality* (Loewenstein & Elster, 1992). Neglecting the internality results in suboptimal choice.

Described in chapter 3, participants in the previous studies investigating choice under the Herrnstein procedure have usually experienced the experimental contingencies through interaction with a computer programme (cf. Sokolowski, 1996). The computer varies the values of the two alternatives according to a simple algorithm. On any individual trial, responding on one of the schedules is worth more than the other schedule but causes the value of both to depreciate over subsequent trials. Conversely, responding on the other schedule, although worth less immediately, increases the value of responding on both schedules over subsequent trials, and so contributes to a larger, overall pattern of reward. In these terms, self-control can be seen as acting in ways that deliver relative small immediate rewards but that contribute to a greater overall pattern of reward (Rachlin, 1995a).

4.2 The Choice Procedure

In the Herrnstein procedure, the current values of both schedules are dependent on the responses made in the preceding trials, and are separated by a constant differential amount. For example, in an experiment where the participants were rewarded for scoring points, which are often presumed to act as reinforcers because of humans' extensive history of dealing with points (e.g., Logue et al., 1986), the points available for each choice of schedule, A and B, could vary according to the following rules:

1. Each choice of A delivers N points.
2. Each choice of B delivers ($N + 3$) points.
3. N equals the number of A responses made in the preceding 10 trials.

These rules generate the parallel, linear reward functions shown in Figure 4-1. Depending on the responses made in the preceding 10 trials, on any given trial, schedule A delivers between 0 and 10 points and schedule B delivers between 3 and 13 points. The mean line indicates the weighted average outcome per trial as a function of the average number of A responses in the preceding 10 trials.

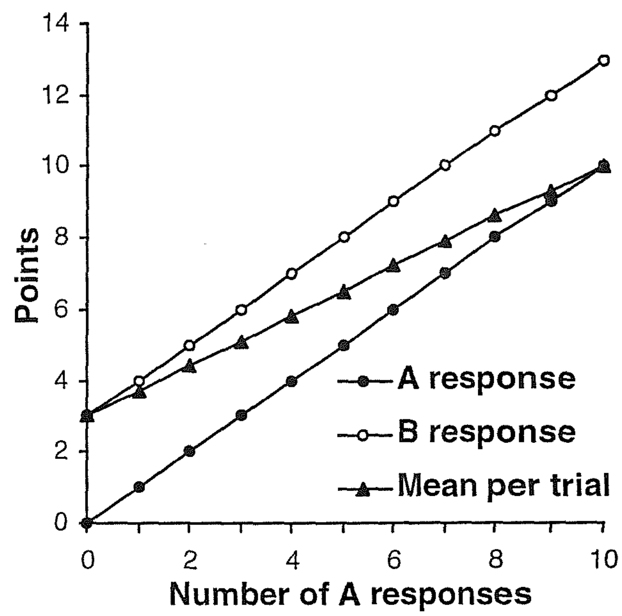

Figure 4-1. Value of an A or a B response (differential of +3) as a function of the proportion of A responses in the preceding 10 trials. The mean line indicates the weighted average outcome per trial as a function of the average number of A responses in the preceding 10 trials. The dashed line at 10 on the y-axis is presented for visual clarity.

On any individual trial, regardless of the preceding choices, greater immediate benefit is obtained by choosing schedule B because the reward is always greater by 3 points than schedule A. However, because of the relationship between the two schedules, choosing this option maximises only local reward. To maximise global reward over a series of trials it becomes necessary to choose schedule A. This is because, repeatedly choosing A drives up the value of N and thus increases the value of both schedules on subsequent trials. In comparison, repeatedly choosing B reduces the value of N and thus causes the value of both schedules gradually to decrease. For example, if N is initially 0, over 8 trials, consecutive B responses (each worth $N + 3$ points) would score 24 points (8×3) while consecutive A responses (each worth N points) would score 28 points ($0 + 1 + 2 + 3 + 4 + 5 + 6 + 8$) because in this instance each choice of A increases the value of N by 1. Ultimately, consistent A responses will deliver 10 points per trial, compared with consistent B responses that will only deliver 3 points per trial. The algorithm thus provides maximum overall utility for repeated choices of the immediately less valuable reward.

4.2.1 Modifying the Basic Procedure

There is considerable scope for expanding from the basic design while still maintaining the parallel reward functions of the two schedules and thus the critical local versus global character of the procedure. On any given trial, the payouts for both schedules, A and B, are dependent on the same variable, N, but B is always greater than A by a constant *differential* amount. N is a function of the number of A responses (A') in the preceding W trials. The number of trials that effects current outcomes, W, has been termed the *averaging window* by Herrnstein et al. (1993). On any given trial, the value of N is determined by Equation 4-1, where $N_{(Min)}$ is the minimum value of N, $N_{(Max)}$ is the maximum value of N, and (A' / W) is the proportion of A responses within the averaging window.

$$N = N_{(Min)} + \left(\left(N_{(Max)} - N_{(Min)} \right) \times \left(\frac{A'}{W} \right) \right) \qquad (4\text{-}1)$$

Thus, if $N_{(Min)}$ is set at zero, as in most of the previous studies reviewed in chapter 3 (cf. Gray, 1999), and $N_{(Max)}$ equals W, then Equation 4-1 simplifies to $N = A'$ (the number of A response in the averaging window). Consider the rules described in section 4.2. The differential between A and B is 3 points, $N_{(Min)}$ is 0 points, $N_{(Max)}$ is 10 points, and the averaging window is 10 trials. In other words, as demonstrated in Equation 4-2, on any given trial N corresponds to the number of A responses within the last 10 trials.

$$N = 0 + \left((10 - 0) \times \left(\frac{A'}{10} \right) \right) = A' \qquad (4\text{-}2)$$

Whenever possible, the simplest form of the function of *N* has been, and will be, used in the descriptions of the experiments reported in this thesis.

To summarise, the variables that determine the parallel, linear reward functions of the Herrnstein procedure are the differential value, the minimum and maximum values of *N*, and the size of the averaging window. Despite the variability of choice outcomes that can be generated by manipulating these four parameters, the positive correlation between the proportion of A responses and overall reward remains virtually perfect (i.e., $r = .99$).

4.2.2 *Modifying the Context of Choice*

In the Herrnstein procedure, the schedule that maximises local and global reward is dependent on the context of choice and nature of the reward structure of the experiment. Consider the rules where: (1) A is worth *N* units, (2) B is worth $N + 3$ units, and (3) *N* is equal to the number of A responses in the preceding 10 trials. If chosen consistently, the value of a single A response will stabilize at 10 units per trial while the value of a single B response will stabilize at 3 units per trial. If the outcome is a desirable commodity, for example, choosing between different numbers of points later exchangeable for money, then maximum global (overall) reward is obtained through repeated selection of A (e.g. Herrnstein et al., 1993). However, if the outcome is undesirable then maximum global reward is obtained through repeated selection of B. An example of an undesirable outcome would be delay, as in situations where delay is aversive (boring) or where the total delay incurred during the procedure is inversely proportional to the participant's financial reward (e.g., Kudadjie-Gyamfi & Rachlin, 1996). In such cases, maximum global reward is obtained by minimizing the average delay per trial through repeated selection of B.

4.2.3 *Schedule Characteristics*

Regardless of how the parameters of the schedules of reward are manipulated, the schedules maintain some basic characteristics. Although the rewards delivered by each schedule change in accordance with the preceding choices, this does not mean that there will always be a discernible change in outcomes from trial to trial. This is because a given response may not necessarily alter the value of *N* on the subsequent trial. Whether or not such a change occurs depends on the precise sequence of A and B responses that have occurred within the averaging window. Figure 4-2 shows how *N* can change over trials. Given that *N* is dependent on the 10 preceding responses and assuming that those choices alternated 'ABABABABAB', then *N* on the current choice is equal to 5. As the averaging window length is constant, each new choice means the earliest response in the sequence is removed from the register. If the new response is of the same type as the one it succeeds then, although the sequence of previous responses has altered, the value of *N* will not change on the next trial because the actual numbers of A responses within the averaging window remains the same. However, if an A replaces a B response the value of *N* will increase by 1, and conversely, if a B replaces an A the value of *N* will decrease by 1. From the participant's perspective, following an A response, the rewards available on the subsequent trial will either be the same or greater than on the preceding trial, whereas following a B response, the available rewards will either be the same or less than before.

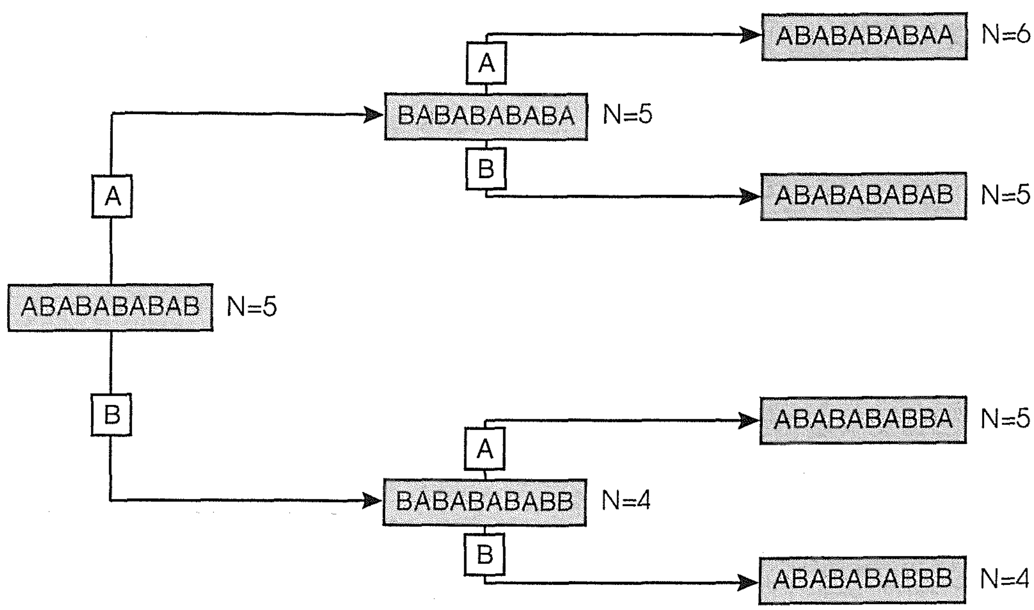

Figure 4-2. Illustration of how the value of *N*, the number A responses in the preceding 10 trials, can change over 2 trials. The grey boxes represent the averaging window of the 10 previous responses, with the earliest response (i.e., the response made 10 trials previously) displayed on the far left and the more recent responses arrayed rightward. The arrows represent a response, either A or B, that leads to the next trial. Each new response results in the earliest response in averaging window being removed and the new response being added in the rightmost position. The value of *N* is then recalculated.

The economic benefit of choosing the global option in the Herrnstein procedure is not immediate. On any given trial, the local outcome is always better than the global by the constant differential. Only through repeated global responding, that results in the value of N gradually increasing, does the global option become more beneficial in terms of maximising overall reward. This is exemplified in Figure 4-3, that shows the cumulative value of consistently choosing either A or B. However, because a minimum number of trials are required for the global option to be beneficial, when the number of trials is limited the optimal choice will change. Therefore, towards the end of a series of trials it will become beneficial in terms of maximising overall reward to switch over to the immediately greater alternative despite the fact that this causes the value of N to decline. For example, given optimal scoring under the rules presented above (A = N; B = $N + 3$), it is economically rational to switch to schedule B on the last 3 trials (if known) because A responses would score 30 points (10 + 10 + 10) while B responses would score 36 points (13 + 12 + 11).

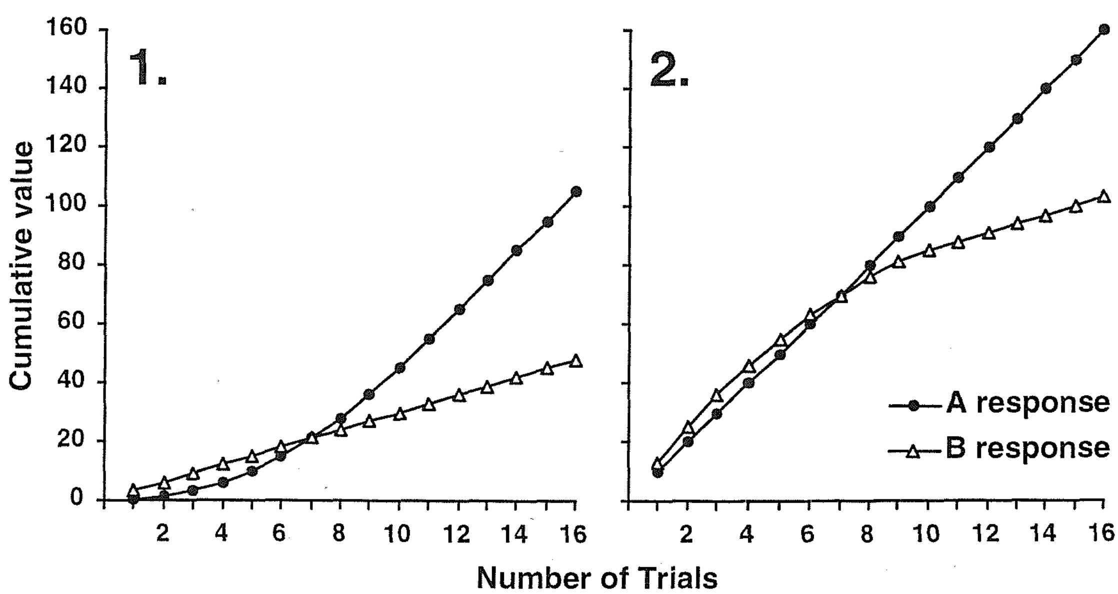

Figure 4-3. Illustration of the cumulative value of consecutive A or B choices. The value of each choice is dependent on the following rules: (1) each A is worth N, (2) each B is worth $N + 3$, and (3) N equals the number of A responses in the preceding 10 trials. The starting sequence of previous responses on graph 1 is 'BBBBBBBBBB' and on graph 2 it is 'AAAAAAAAAA'. In each case, given responses exclusively made on one schedule, for the first six responses the cumulative value of A is less than B. However, through repeated choice, the value of a single A becomes greater than a single B, and thus after 8 trials the overall value of A becomes greater.

4.3 Behavioural Measures

Previous published studies using the Herrnstein procedure, described in chapter 3, have collected and analysed two principal sources of data. The primary dependent variable, a measure of performance in terms of global maximisation, was determined by whether the specific procedure employed a trial constraint or a time constraint. Under a trial constraint, the dependent variable was the proportion of responses made on each schedule over a number of trials (e.g., Herrnstein et al., 1993). In comparison, under a time constraint, when the dimension controlled by the Herrnstein procedure was the delay between trials, the dependent variable was the number of trials completed within the time limit (e.g., Kudadjie-Gyamfi & Rachlin, 1996). Whichever dependent variable was incorporated into the experiment, it was either analysed as a whole for the entire session, or it was divided into blocks and each block examined to determine the time course of any effects. For example, in several of the studies reported by Herrnstein et al., the analysis focused primarily on the responses made in the latter half, or latter third, of each session because Herrnstein et al. were mainly interested in the final strategies adopted by the participants and in the earlier parts of the session the participants were deemed to be learning about the contingencies. In addition to measuring the actual responses made, Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996) attempted to assess each participant's explicit knowledge of the experimental contingencies by collecting verbal protocols at the end of the session. The analysis of verbal data is invariably problematic because such data is liable to be corrupted by subjective interpretation (see Ericsson & Simon, 1993). Precisely how verbal protocols were collected in these studies is unclear, and the analysis was limited to a qualitative comparison of the participants' expressed knowledge of the contingencies and their actual responses.

4.4 Design Considerations

Several fundamental design decisions had to be made before the more specific details of the experiments in this thesis could be developed. The underlying basis for these decisions was the aim to conduct experiments that would be comparable with, and further the original research of Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996). These earlier studies adopted a group design and it was decided to continue with this approach rather than diverge and investigate single subject designs. Although it is important to remember that data averaged across a group does not necessarily represent the performances of individuals within the group there is justification in generalising such results to the wider population.

Once a group design had been settled on the practicalities of running such an experiment in a university setting became important. On the grounds of availability and (relative) easy of recruitment it seemed sensible to use students as participants in these studies. Students were initially encouraged to participate by offering financial rewards. In addition, those who were themselves studying psychology could earn credits which would entitle them to use the departmental participant pool for their own research. The final factor that had to be considered was the number of trials and the length of an experimental session. Although maximising the number of trials was considered desirable, the length of time the a participant would happily participate was an issue. From initial pilot studies and general intuition it was decided that a session should last no longer that 45 mins.

4.5 Programming the Software

All the experiments reported in this thesis used a computer to present the experimental contingencies and record the participants' responses. The computer was located in a small research cubicle (1.5 m by 3 m), the basic layout of which is shown in Figure 4-4.

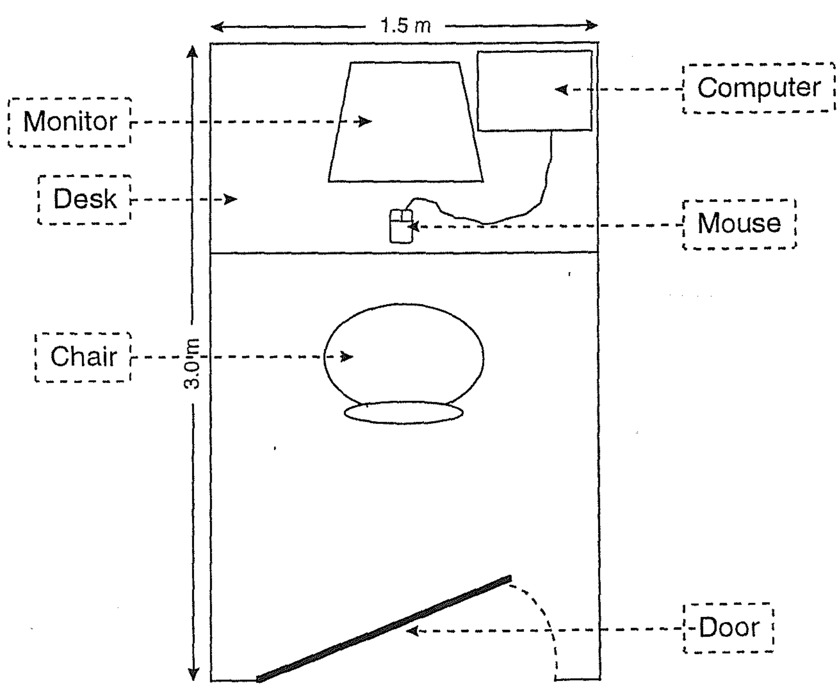

Figure 4-4. Basic layout of the research cubicle used to test the participants.

The applications were written by the author using Borland Delphi for Windows, a programming environment that uses the Object Pascal language. Although each study required a new application to be written, they all followed the same basic design. Each program was based around two main forms (or windows), a control-form and a trial-form. The control-form, an example of which is shown in Figure 4-5, allowed the experimenter to easily manipulate the experimental conditions by simply changing the values in standard Windows' editboxes, and by selecting the relevant checkboxes and radiobuttons. For ease, this process was automated so that the experimenter could type in the group number to which the participant was assigned, and the program would automatically assign the correct conditions. The trial-form formed the basis of the participant's interface and presented the contingencies, and information regarding those contingencies, to the participant. Depending on the study, this screen displayed information such as the participant's current score, the trial number, time remaining, and so forth. Each trial-form is described in more detail in the relevant chapter.

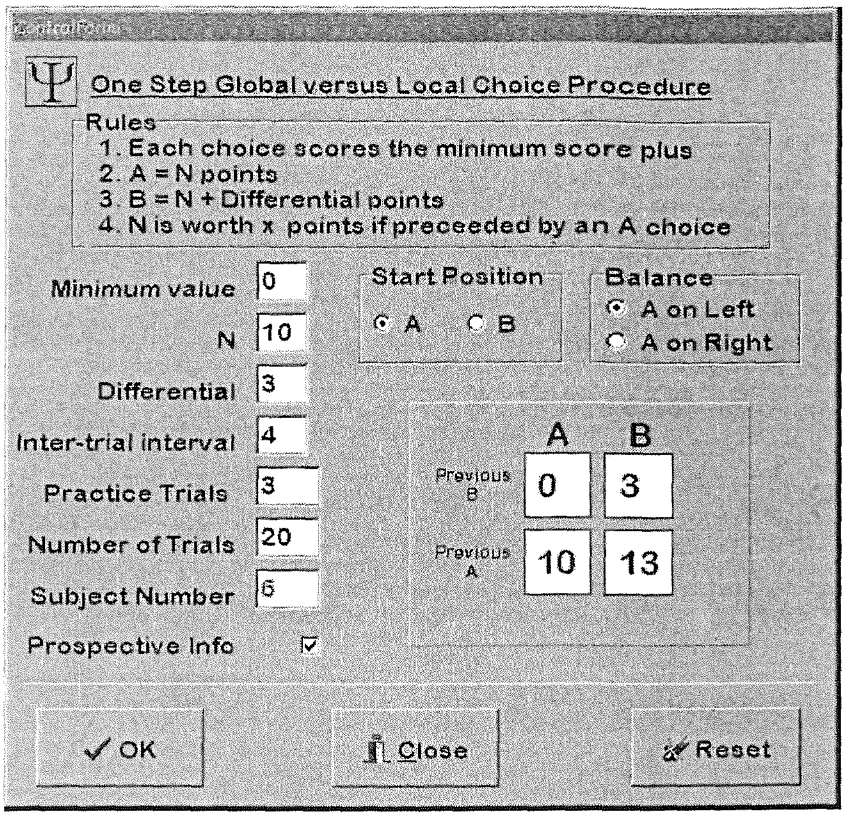

Figure 4-5. Screenshot of a Control-Form. This form allowed the experimenter to set-up the specific conditions of the experiment by changing the values in the editboxes, and by selecting the relevant checkboxes and radiobuttons.

In addition to the two main forms, other windows were used to inform the participant about which stage of the procedure they were about to begin (i.e., practice stage or experimental stage) and when they had finished the session. During study one, the instructions were also presented on the computer screen, but this was dropped in later studies owing to both the author's personal preference for reading from paper and the views expressed by some participants.

The program recorded the group number, subject number, the responses made by each participant, and their response latencies. At the end of each session, the data for each subject was accumulated in a single text file (for an example, see Appendix A), that was formatted so that it could easily be imported into another application, such as a spreadsheet.

4.6 Pilot Studies

Before each experiment was conducted pilot studies were performed on a small number of participants. The primary aims of these pilot studies were to test the robustness of the computer program and the clarity of the instructions and questionnaires. In addition, however, the pilot studies also gave the experimenter the opportunity to assess the effects of the experimental manipulations, although this was merely an intuitive assessment and not a statistical one because of the small sample sizes. For these reasons no further information about the pilot studies will be discussed.

Chapter Five - Factors Affecting Human Choice in a Local versus Global Choice Paradigm[2]

5.1 Rationale

The aim of this first experiment was to integrate the research findings based on the traditional SS versus LL model with the newer framework proposed by Rachlin (1995a), and to further our understanding of the factors that influence behaviour under conditions in which local and global rewards are opposed. The experiments reviewed in chapter 3 have provided evidence that humans are sensitive to the contingencies of global choice, but few factors have so far been examined. It was assumed that variables found to effect self-control in studies based on the traditional model should, if suitably translated, affect choice responding under local versus global conditions.

At least three classes of variable that influences self-control can be identified from the research reviewed in chapter 2. These are (1) motivational factors, (2) cognitive factors, and (3) social comparison factors. The impact of motivational variables such as the difference in reward magnitudes and the prereinforcement delay preceding the SS and LL rewards has been widely studied (see Herrnstein, 1981; Logue, 1988, for reviews). Cognitive factors provide prospective information about the value or salience of future outcomes. Essentially, they facilitate the formation of rules regarding the overall benefits of the choice alternatives. Such manipulations are used in studies that (1) replace direct experience of the contingencies with verbal instructions concerning expected outcomes (e.g., Navarick, 1986) or (2) use instructions to help participants to conceptualise future reinforcers differently (e.g., emotionally or neutrally). Mischel and colleague have made an extensive study of this form of verbal control (see Mischel et al., 1989). Finally, social comparison factors such as modelling (e.g., Bandura & Mischel, 1965) affect the participants' knowledge of the way other behave and the outcomes they have achieved when faced with the same choices.

Motivational, cognitive and social informational variables may also influence behaviour in the local versus global choice paradigm. The present experiment examines the

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[2] A report of this experiment was published as:

Warry, C. J., Remington, B., & Sonuga-Barke, E. J. S. (1999). When more means less: Factors affecting human self-control in a local versus global choice paradigm. *Learning and Motivation, 30,* 53-73.

effects of these variables using an experimental task based on the Herrnstein procedure (Herrnstein et al. 1993).

5.2 Method

5.2.1 Design

Participants received 200 successive choice trials between two concurrently available alternatives, A and B. Although the values of both A and B varied according to an algorithm (see section 5.2.3), the value of B always remained higher than that of A by a constant amount (the differential). The primary dependent variable was the proportion of A responses made during the experimental session. In addition, response latencies were recorded on a trial by trial basis. The experiment used a 2 x 2 x 2 nested factorial design, shown in Table 5-1, to assess the effect of three independent variables on the proportion of A responses and response latencies. The first independent variable was the points differential between the two immediate choices, A and B (3 points versus 7 points). The second variable related to the availability of prospective information (regarding the value of the A and B responses on the next trial) that was provided to the participant. The third variable related to the availability of social comparison information allowing the participant to compare his or her performance with "an expert". The two levels of the prospective and comparison variables were determined by whether prospective or social comparative information was, or was not, available to a participant.

Table 5-1

Design of Experiment 1

Differential	+3				+7			
Prospective	No		Yes		No		Yes	
Comparison	No	Yes	No	Yes	No	Yes	No	Yes
Group	1	2	3	4	5	6	7	8

Following the test, participants completed a short questionnaire (see Appendix B) designed to determine their awareness of the local-global contingencies under which they were choosing.

5.2.2 Participants

112 students (45 males and 67 females) were recruited from the departmental participant pool. Their ages ranged from 18 to 35, with a mean age of 21.7 years (SD = 3.6). Participants were randomly assigned to one of the eight experimental groups, and were paid for their participation, as stipulated in the instructions (see section 5.2.4).

5.2.3 Apparatus

Participants were tested individually in a small windowless cubicle (1.5 m by 3 m) containing a desk, on which was mounted an Elonex 486-DX50 PC with a soundcard, a 15 inch SVGA monitor (resolution: 800 by 600 pixels), and a mouse with two equal size buttons. The experimental conditions were programmed as a Microsoft Windows 95 application using Borland Delphi 3.

Figure 5-1 shows a diagram of the subject interface. In all conditions, the message 'CHOOSE NOW' was displayed in red at the top at the start of each trial. The interface also included the grey vertical bar in the centre of the screen that was used to indicate a participant's score (points). This was calibrated at 10 point intervals and allowed up to 100 points scored to be displayed as a vertically advancing yellow band. When 100 points were obtained, the score bar cleared and a small image of a completed bar appeared next to the main bar. Completed bars accumulated each 100 points scored. To avoid any choice bias caused by the positioning of the completed score bars, they appeared sequentially on the left and right side of the main score bar. The panels in the two bottom corners of the screen were only present in those conditions in which prospective information was provided. The numerals shown in these panels told the participant the number of points that would be obtained by choosing either left or right (A or B) at the next opportunity. For example, in Figure 5-1, the participant would score 5 points if they pressed the left mouse button or 8 points if they pressed the right mouse button. This additional information was not available during the inter-trial interval.

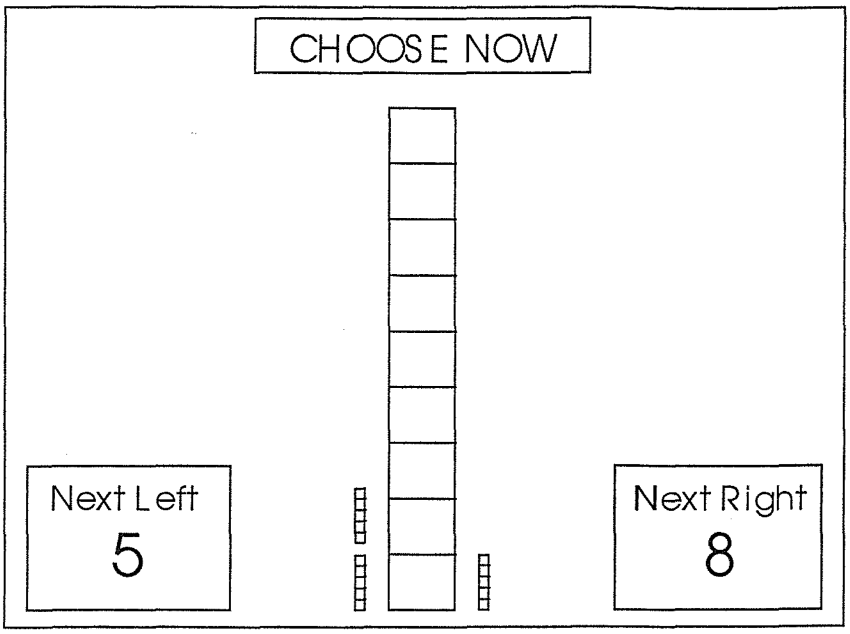

Figure 5-1. Screen display. This display told participants when they could choose and how many points they had scored. The central score bar displayed 0 to 100 points. When 100 points were scored, the central score bar cleared and a small image of a complete score bar appeared next to the main bar. The panels in the bottom corners of the display were only available in the prospective information condition, and showed the value of left and right choices on the current trial.

When required, social comparison information could be displayed graphically by 'sliding' the score bar(s) to the left and then displaying an "expert's score" in the form of an additional vertical bar and/or completed bars to its right. An example of how this screen looked after the animation is shown in Figure 5-2. The expert's score was always the maximum score for the number of trials based on the optimal choice strategy. After 4 s, the screen returned to the layout shown in Figure 5-1. To control for the stimulus change, participants who did not receive social comparison information saw a single consonant displayed instead of the expert's score. Consonants appeared in the same sequence for each participant: 'BWMFPDZGJLYNKCHRVTS'.

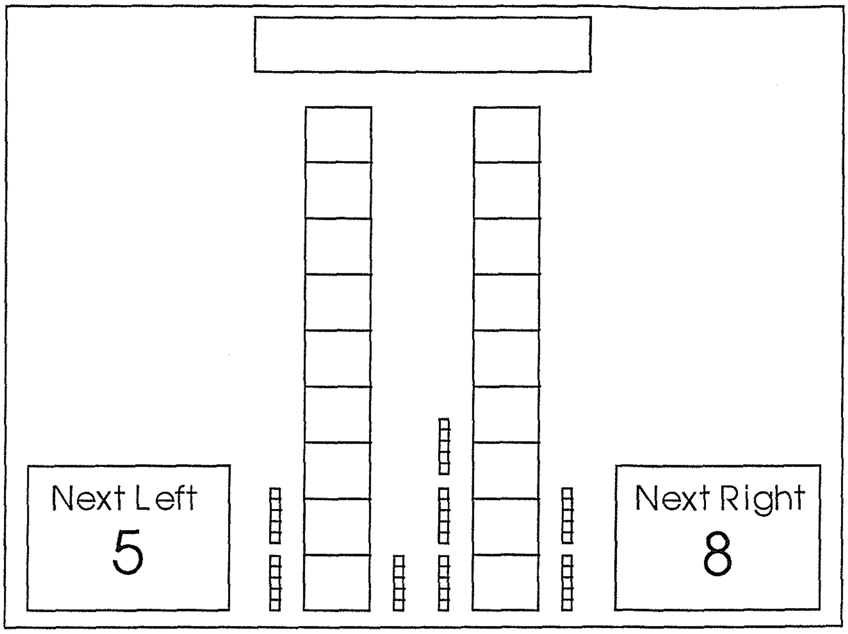

Figure 5-2. Screen display. This display allowed a participant to compare the number of points they had currently scored, shown by the score bars on the left, with the number scored by an "expert", shown by the score bars on the right.

The program instantiated an algorithm for awarding points for A and B responses. On any trial, the score available for each choice was dependent on the number of previous A responses according to the following rules:

1. A is set less than B by a constant differential value (either 3 or 7 points)
2. Each choice of A adds *N* points
3. Each choice of B adds *N* points plus the differential value
4. *N* equals the number of times A has been chosen in the previous 10 trials.

Figure 5-3 shows how these rules determine the points contingent on an A response or a B response as a function of the number of A responses in previous ten trials. It also indicates the average number of points earned per trial as a function of the average number of A choices in the previous 10 trials (assuming this pattern of choice is stable). Repeatedly choosing the lower value alternative (A) will drive up the value of *N* and thus the value of both alternatives. However, choosing the higher value alternative (B) will gradually reduce the value of *N* and thus in the longer-term the value of both alternatives will gradually fall below the starting value of the initially lower value alternative, A. At this point, only repeated selection of A can redeem the value of both alternatives to starting levels.

For both values of the differential variable, the positive correlation between the proportion of A responses and final score is virtually perfect ($r = -.99$; $p < .01$). If A is chosen consistently over the 200 trials the participant's final score will be 1970 points. If B is chosen consistently the final score will be either 625 points, if the differential is 3, or 1425 points, if the differential is 7. The algorithm thus provides maximum overall utility for repeated choices of the smaller reward.

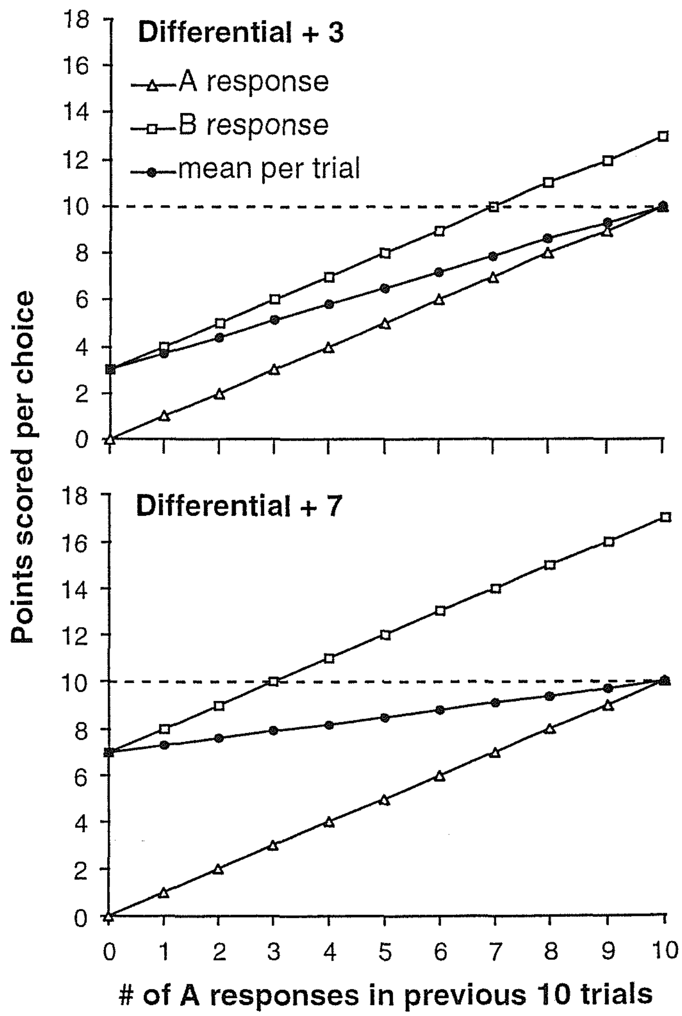

Figure 5-3. Number of points contingent on an A response or a B response as a function of the number of A responses in the previous 10 trials. The mean line indicates the average number of points per trial as a function of the average number of A responses in the previous 10 trials. The dashed line at 10 on the y-axis is provided for visual clarity.

5.2.4 Procedure

Participants were seated individually in front of the computer and asked to read the instructions displayed on the screen. They were also provided with an appropriate printed screenshot (modified as necessary from Figure 5-1). The general instructions read as follows:

> Thank you for taking part in this experiment. Please read these instructions carefully and please ask about anything that isn't clear.
>
> The aim of this task is to score points. You will earn 1 penny for every 5 points you score. Points are scored by pressing the left and right buttons on the mouse. However, only one button can be pressed at a time, so each time you are asked to make a choice you must decide which button to press. You will have 200 choices to score as many points as you can. Please look at the diagram of the experimental display, which you will find next to the computer. The screen will be laid out as follows:
>
> At the top of the screen is a box. When 'CHOOSE NOW' is displayed here in red you should make your next choice. In the middle of the screen is the display of your score. Initially, all you will see is the vertical score bar. The score bar is divided into ten blocks, each of which displays 10 points. So, in total, the score bar displays 0 to 100 points. Every time you reach 100 points (i.e. you completely fill the score bar) you will have earned 20p. When this happens, the bar will reset to zero and a small picture of a completed bar will appear. These completed bars appear sequentially to the left and then to the right of the main bar.

The following instructions were added to the general instructions for all participants in the prospective information condition.

> In the bottom corners of the screen are two boxes. These will show you how many points you will score for a left or right choice on the next occasion. Please look at the screenshot. In this example, choosing the left button would score you 5 points and choosing the right button would score you 5 points.

The following instructions were added to the general instructions for all participants in the social comparison condition.

> After every tenth choice you will be able to compare your score with that of an expert. When this happens your display will slide to the left and a display showing the expert's score will appear on the right. After a few seconds the expert's score will disappear and your display will slide back into the middle.

The following instructions were added to the general instructions for all participants who were not in the social comparison condition.

> After every tenth choice there will be a simple letter recognition test. When this happens your display will slide to the left and a letter will appear on the right. After a few seconds the letter will disappear and your display will slide back into the middle. We would like you to count the number of vowels that appear over the entire task.

The remaining instructions below introduced the warm-up task and were presented to all participants.

> To get you used to the study we will give you 10 choices during which both the left and right buttons will score 5 points. This trial period doesn't count for anything, it is just to allow you to get used to the display and making your choices. Once you have finished this practice session the machine will reset and you can start the actual task. Remember, in the actual task, you have 200 choices to score as many points as possible and you will be paid 1 pence for every 5 points scored. Please ask if you have any questions. When you are ready, please click the mouse cursor on the OK button.

A trial began when the words 'CHOOSE NOW' appeared on the screen. The participant made a choice by pressing either the left or right button on the mouse which led to an immediate change in score displayed on the vertical bar, followed by an inter-trial interval of 4 s. Response latencies for both A and B choices were measured from the end of each inter-trial interval, when 'CHOOSE NOW' appeared on the screen to the time when a mouse button was pressed. To avoid a possible left/right bias, the function of the response keys was counterbalanced (i.e., half the participants in each group made an A choice on the left button and half made an A choice on the right button). All participants were given 10 warm-up trials to familiarise themselves with the screen display and the controls. During these trials both buttons on the mouse scored 5 points. On completion of the trial phase the experimenter left the cubicle.

At the start of the experimental phase of the study, the register of previous choices that determined the value of N was pre-set at 5, with the sequence 'ABABABABAB'. The participants were then given 200 trials, during which points were awarded according to the algorithm described in section 5.2.3. After every block of 10 trials, participants in the social comparison condition received the "expert's score" display for 4 s. The remaining participants received the control consonant display for the same length of time.

Following the completion of the choice procedure, participants were instructed to fill out a questionnaire designed to assess their awareness of the algorithm underlying the pattern of point delivery. The questionnaire was scored on a scale of 0 to 3. A score of 0 was given if the participant's answers indicated no knowledge of the rules. A score of 1 was given if the participant knew that B lowered the immediately available points while A raised them, but still thought that overall it was more advantageous to choose B. A score of 2 was given if A was identified as the better choice overall but the participant believed that the optimal strategy involved switching between the two choices. A score of 3 points was given if the participant knew that the optimal strategy involved consistently choosing A. All questionnaires were independently assessed by two judges. The inter-rater reliability of this measure, calculated by Spearman's rho, was $r_s = .64$; $p < .01$.

5.3 Results

The effect of each of the three independent variables on the mean proportions of A responses is shown in Figure 5-4. A series of one-sample *t* tests revealed that the mean scores for both levels of each of these variables fell significantly below 50%, (i.e., indifference between the two available choices; all $t(55) < -3.33$, $p < .05$). Thus, there was a greater tendency for participants to choose the larger local reward (B).

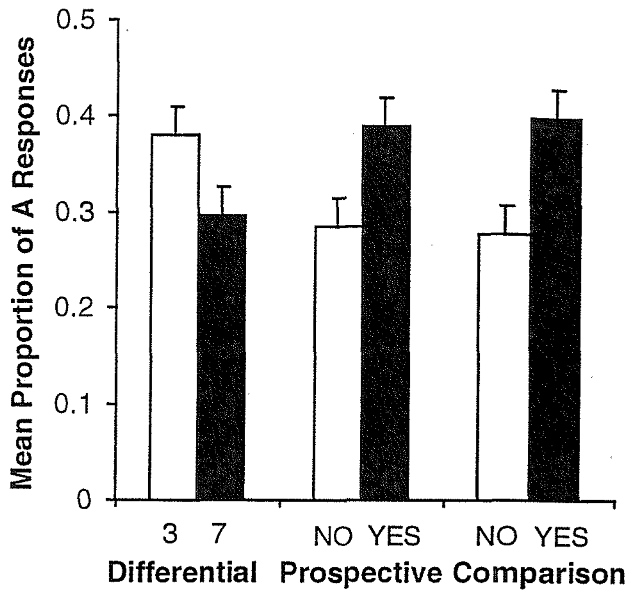

Figure 5-4. Mean proportion of global (A) responses by factor. One standard error is shown above the mean.

Before subjecting these data to ANOVA, an exploratory analysis of the time-course of any effects that the independent variables had on the proportion of A responses was carried out. The 200 choices were divided into 5 blocks of 40 trials (Blocks 1-5). Figure 5-5 shows the proportion of A responses per block made by each group. To the groups receiving both comparison and prospective information (groups 4 and 8), curves were fitted to predict the progression of the proportion of A responses against block. Inverse functions proved a good fit for both groups: differential +3: $R^2 = .96$, $F(1, 3) = 79.09$, $p < .05$; differential +7: $R^2 = .98$, $F(1, 3) = 125.87$, $p < .05$. As the number of blocks increased, these functions tended towards the asymptote of .67 (differential +3) and .66 (differential +7).

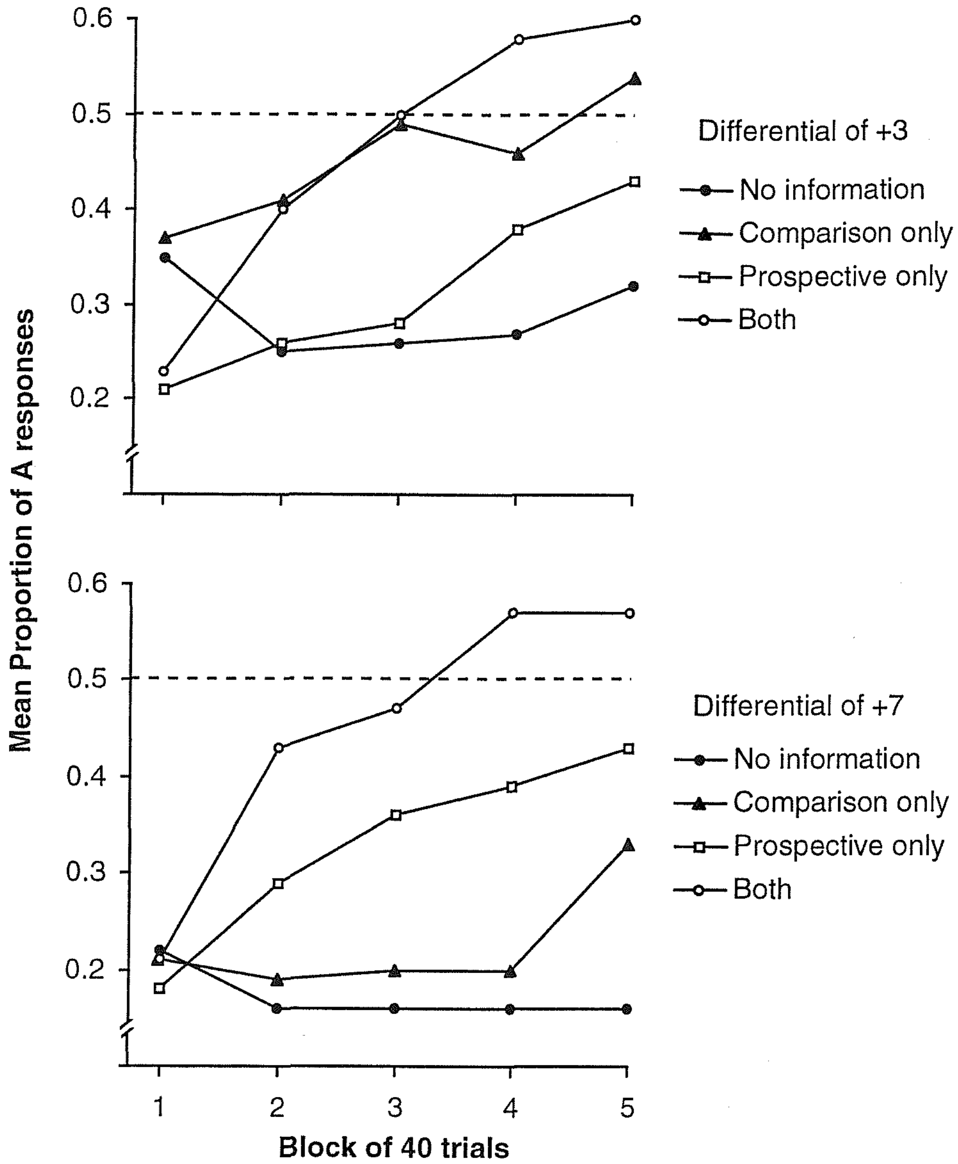

Figure 5-5. Mean proportion of global (A) responses per block of 40 choices shown for each group. The dashed line at 0.5 of the y-axes represent indifference between the two available choices.

The mean proportion of A responses per block for each condition was calculated and a mixed-design ANOVA (Differential x Prospective Information x Social Comparison x Block) was used to determine main effects and any interactions between the variables. The initial analysis, excluding block, showed that all three main effects were significant. The mean proportion of A responses decreased as a function of the increase in the differential reward value indicating that participants selected the global choice less frequently when the differential between choices was greater, $F(1, 104) = 4.28$, $p < .05$. Conversely, the mean proportion of A responses increased when participants were provided with either prospective information or social comparative information, $F(1, 104) = 6.41$ and 8.71, respectively, $p < .05$. These results are shown in Figure 5-4.

There was a significant interaction between the differential and prospective information factors, shown in Figure 5-6, $F(1, 104) = 4.50, p < .05$. Tests of simple main effects showed that, in the absence of prospective information, significantly fewer A responses were made when the differential was 7 points than when it was 3 points, $F(1, 54) = 9.42, p < .05$. However, there was no significant difference between the levels of the differential factor when prospective information was provided, $F(1, 54) < 1$. The level of prospective information made no significant difference when the differential was 3 points, $F(1, 54) < 1$, but without prospective information there were significantly fewer A responses when the differential was 7, $F(1, 54) = 12.81, p < .05$.

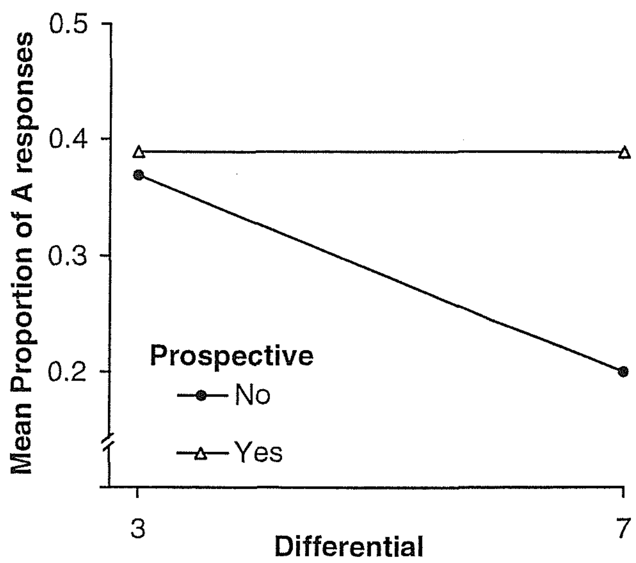

Figure 5-6. Mean proportion of global (A) responses showing the interaction between the differential and prospective information factors.

The mixed design ANOVA was also used to identify a main effect of block and interactions between block and the three key variables. Because the data violated the assumption of homogeneity of covariance, the Greenhouse-Geisser correction was used to modify the degrees of freedom to make the test more conservative (see Howell, 1997). The results showed a significant effect of block, indicating a increase in the number of A responses as the session progressed, $F(1, 104) = 23.94, p < .05$. No interaction was found between the differential and block variables, $F(1, 104) < 1$, but there were significant interactions between prospective information and block and comparative information and block, $F(1, 104) = 16.33$ and 5.00, respectively, $p < .05$. The time-courses of the effects for each of the factors are shown in Figure 5-7. Further analysis showed that the availability of prospective information produced significantly fewer A responses during the first block, $t(110) = -2.52$, $p < .05$, but significantly more on the second, $t(110) = 2.17$, $p < .05$, and subsequent blocks, $t(110) = 2.33$, 3.83 and 2.83 ,for Blocks 3, 4 & 5 respectively, $p < .05$. Provision of comparative information had no effect on the proportion of A responses made in the first block, $t(110) = 0.56$, $p > .05$, but produced significantly more A responses in the second, $t(110) = 2.58$, $p < .05$, and subsequent blocks, $t(110) = 2.82$, 2.66 and 2.91, for Block 3, 4 & 5 respectively, $p < .05$.

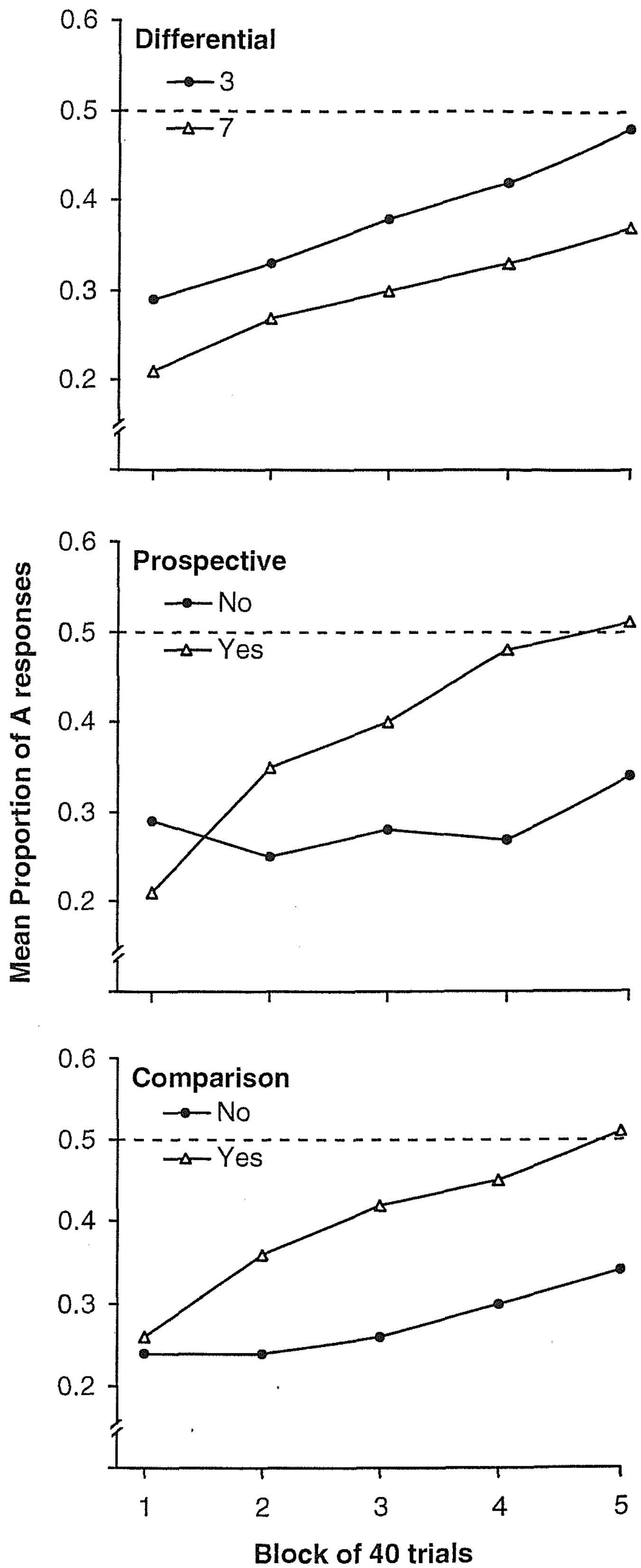

Figure 5-7. Mean proportion of global (A) responses per block of 40 trials shown for each factor. The dashed line marked at 0.5 on the y-axes denotes choice indifference between the two alternatives.

The post-experimental questionnaire showed that participants' awareness of the algorithm underlying variation in reward value was generally poor. Table 5-2 shows that few of the participants (58/112, 7%) were rated as having understood the experimental conditions while the majority (58/112, 52%) were rated as having no knowledge of the rules. Spearman's test of rank correlation showed a significant correlation between awareness of the local-global contingencies and the proportion of A choices made ($r_s = .65, p < .01$).

Table 5-2

Number of Participants and Mean Proportion of A Responses by Level of Awareness

		Proportion of A responses	
Awareness	*n*	*M*	*SD*
0	58	.21	.20
1	35	.39	.15
2	11	.54	.11
3	8	.76	.15

The mean response latency was calculated for each participant. There was no significant correlation between mean response latency and the proportion of A responses made, $r = -.004, p > .05$. Again the 200 choices were divided into 5 blocks of 40 trials (Blocks 1-5) and the mean response latency per block for each condition was calculated. A mixed-design ANOVA (Differential x Prospective Information x Social Comparison x Block) showed that there was no main effect of differential, prospective information or social comparison, $F(1, 104) = 0.51$, 1.63, and 1.50 respectively, $p > .05$. However, despite incorporating the Greenhouse-Geisser correction, there was a main effect of block, $F(1, 104) = 11.67, p < .05$, and an interaction between prospective information and block, $F(1, 104) = 5.47, p < .05$. The main effect and the interaction are shown in Figure 5-8. Analysis of the main effect using paired *t* tests showed a significant decrease in the response latency between Block 1 and Block 2, $t(111) = 3.81, p < .05$, and between Block 2 and Block 3, $t(111) = 3.65, p < .05$, but no significant difference between the later blocks. Independent *t* tests were used to examine the interaction, and showed that on Block 1, the provision of prospective information led to significantly longer response latency, $t(110) = 2.31, p < .05$, but that there was no significant differences between the levels on the later blocks.

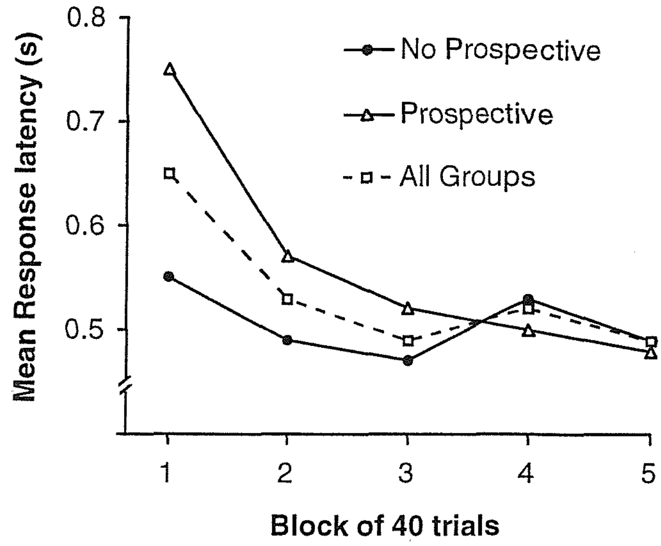

Figure 5-8. Mean response latencies per block of 40 trials for the prospective information factor and all groups combined.

Because awareness of the global contingency was found to be associated with improved performance, the relationship between awareness and latencies was also examined. The mean response latencies by level of awareness are shown in Table 5-3. Because of the unequal group sizes, a Kruskal-Wallis test was used to determine whether there was a relationship between awareness level and mean response latency. The result of this analysis showed that there was no significant effect, $H = 0.40, p > .05$.

Table 5-3

Mean Response Latency by Level of Awareness

		Response latency (s)	
Awareness	*n*	*M*	*SD*
0	58	0.53	0.24
1	35	0.50	0.13
2	11	0.61	0.41
3	8	0.55	0.23

The raw data from this experiment are presented in Appendix C.

5.4 Discussion

The most striking finding of this study was the relative lack of sensitivity to the overall contingency. There was a strong tendency for participants to choose the larger of the two immediate rewards despite the fact that, given the near-perfect correlation between choices and points earned, choosing the smaller local reward would have been more beneficial in terms of maximising global reward. Moreover, extrapolation of the data for the groups with both the prospective and comparison information (groups 4 and 8) strongly suggests that the pattern of choice would asymptote at a non-optimal level (see Figure 5-5). Given that these two groups had the most information it would seem likely that the remaining groups would eventually asymptote at a similar level or below. Although such a pattern is consistent with the previous findings using this paradigm (e.g., Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996), this study furthers earlier research by furnishing strong evidence that the basic effect can be moderated by motivational, and cognitive or social informational factors. Thus, the group of participants that were exposed to a greater incentive for selecting the larger reward (a differential value of 7) and that received no additional prospective or social comparison information showed virtually no increase in the frequency of global choices across the 200 trials but all other groups showed some trend towards global choice. Although the strength of this trend varied across groups, even the most reactive of them (those experiencing small incentive differential plus provision of cognitive and social information) did not by the end of the experiment approach a pattern of behaviour optimal in terms of maximising overall reward.

Over the entire session, global choices were made more frequently by those participants choosing between outcomes with the smaller (3) points differential than those with the larger (7) points differential. It is reasonable to suppose that participants' history of reinforcement with simultaneous choice situations is likely to dispose them to choosing the larger reward initially, particularly under conditions where they are uncertain about the optimal response strategy. Although the arithmetic "solution" that maximises overall reward does not vary with reward differential, the number of choices necessary to pass the point at which repeated global choices pay off in terms of overall reward rate increases with the value of the differential (see chapter 4 for a more detailed description). Thus, there are two related reasons why a large reward differential may reduce the likelihood of a pattern of global choice. First, the larger the differential reward value, the greater the need to be sensitive to the accumulative effects of longer chains of consecutive choices. This can be seen graphically in Figure 5-3 by the reduction in the slope of the average function associated with an increase in the differential. Second, the immediately damaging effect of each global choice in terms of local rate (i.e. the points foregone immediately as a result of that choice) is highly salient when the differential is larger.

This analysis suggests that attention should be paid to the factors likely to overcome normal patterns of behavioural variation in simultaneous choice situations. Rachlin (1995a) theorises that factors that frame the immediate choice within a wider context will promote global choice by improving the salience of the global contingency. Kudadjie-Gyamfi and Rachlin (1996) manipulated context by requiring their participants to make choices in sets of three trials, hypothesizing that structuring choice in this way would emphasize the longer-term effects of each immediate choice. Their findings showed that grouping did indeed lead to an increase in the number of global choices when compared to singular choices. To Rachlin (1995a), the instructional effects often shown to facilitate self-control in the more traditional paradigm (e.g., Mischel et al., 1989) can also be interpreted in terms of providing a wider context for choice behaviour. On this view, contextual information can potentially take many different forms. The context manipulated of the present study was through the provision of prospective and social comparative information.

As hypothesised, the provision of prospective information increased the frequency of global responses. However, the time-course of this effect was not consistent. Over the first 40 trials, contrary to expectation, the provision of prospective information actually reduced the likelihood of global choice (see Figure 5-7). This further supports the view that there is a predisposition to choose the immediately larger reward when the optimal strategy is uncertain because the additional information initially made the immediate reward differential more salient. In the longer term, however, prospective information functioned as response-produced feedback. In other words, the information was dependent on the immediately previous choice, with each global choice producing cues indicating more favorable response alternatives than on the previous trial and each choice of a larger reward producing cues indicating a less favorable pair of options. It is possible to interpret these cues as functioning as reinforcers because, as the comparison between prospective and non-prospective groups indicates, their contingent presence eventually acted to increase the frequency of global choices. However, it is unlikely that informational cues acquired their reinforcing capacity as a result of any simple associative learning process; rather, their efficacy was almost certainly dependent on the fact that the information they provided allowed participants to develop response strategies in relation to the global contingencies, although the effectiveness of such strategies can be questioned (see below).

The provision of social comparison information allowed participants to determine whether their current behaviour was effective and, as with prospective information, to formulate or refine a response strategy accordingly. As expected, the social comparative information provided by periodically telling participants the "expert's score" increased global choices. However, in contrast to the effect of prospective information, there was no effect of social comparison information until the second block of 40 trials (see Figure 5-7). Participants needed to experience comparative feedback on several occasions before the information began to have an impact on their choices. Even with this informational advantage, however, few acquired an optimal response strategy. There is some room to question whether the effect of the social comparison variable was truly social (H. Rachlin, personal communication, June 25, 1998). It might be argued that the control for the additional information that the expert's score provided was inadequate because, despite the fact that control participants' points scores remained visible, the interpolated memory task somehow distracted their attention from the choice task. If so, access to the expert's score may simply have provided participants with more time to process information on the relation between responding and points (cf. Kudadjie-Gyamfi & Rachlin, 1996) rather than giving them distinctively social information. If so, further work may be required to determine where the social comparison variable is truly effective in this context.

Despite the fact that the pattern of choices made was significantly affected by motivational, cognitive and social factors, there was still evidence for considerable variability within conditions. It is beyond the scope of this experiment to account for these individual differences in self-control, although it is worth noting that Navarick (1998), studying the traditional model, found individual differences in performance to be fairly stable over time. Within the current experiment, some of the variability undoubtedly arose because different participants made different use of the information provided (or, in Rachlin's terms, different contexts were linked with their experiences). For example, it is noteworthy that the use of social comparison information relies on more than a belief in its veracity: Several participants asserted at post-test that they could never catch up with the expert's score and therefore gradually discounted it as the session progressed.

It has sometimes been argued what seem like straightforward incentive factors also function primarily by providing task-relevant information. For example, Wearden (1988) claimed that using rewards of points later exchangeable for money has little real incentive value for human participants in operant experiments. Instead, like other informational variables, points are simply tokens indicating to participants that their behaviour is appropriate to the experimental demands. This interpretation is only partially supported by the present data, in particular by the significant interaction between differential and prospective information variables. The addition of prospective information had no effect on choice when the reward differential was small but negated the significant decrease in global choices otherwise observed when the differential was large (see Figure 5-6). This suggests that points may not be a powerful enough incentive to overcome the effects of purely cognitive manipulations. Nevertheless, the proportion of global choices remained below 50% even when participants had the advantage of prospective information. Although this suggests that points still have some incentive value independent of their informational role, further research may benefit from the use of more powerful and immediate reinforcers. In terms of immediacy of impact, the use of delay by Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996) has much to commend it, and will be explored in the following experiments in this thesis (chapters 6 - 8).

The possibility that informational manipulations facilitated the formulation of self-instructions has been alluded to above. Whereas both Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996) assessed the effects of providing explicit information (hints) about the rules, this study focused on participants' self-reports of self-generated rules. Post-hoc analysis of participants' self-reported explicit knowledge of the task indicated that, in accordance with the previous studies (Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996), the majority (93%) were unaware of the precise contingencies used in the experiment and consequently failed to identify the best strategy for maximising their outcome in terms of points earned. There was, however, a strong correlation ($r_s = .65$, $p < .01$) between the level of explicit knowledge of the contingencies and the number of global choices made. Unfortunately, it is unclear whether awareness of the task structure preceded improvement in performance or followed it, because the assessment of awareness was only made post-hoc and because the measure was not highly reliable. Although a consideration of response latencies throughout the experiment might provide some indication of the development of rules, these data are also equivocal. No difference was found in overall response latency between the conditions and no correlation emerged between response latency and the proportion of global choices. Latency was longest on the first block but decreased, stabilizing by block three. This pattern may indicate either the early formulation of a (flawed) rule-based response strategy, but they could equally well reflect an implicitly learned minimisation of task delay.

In summary, the present study clearly showed that the three classes of variables identified from the traditional and widely researched self-control paradigm also affect choice in the local versus global paradigm. In addition, these findings can be seen to offer some validity to viewing self-control in terms of local versus global choice. Although the research emphasised the importance that the contextual framing of a choice has on behaviour, even under conditions when all the factors favoured global choice, participants did not respond optimally in terms of the global contingency. Perhaps this is indication of a fundamental tendency to choose immediate gratification, at least occasionally, despite "knowing better".

Chapter Six - Effects of Differential Size

6.1 Rationale

A key procedural difference between studies employing human and non-human participants is the nature of the consequences or rewards that they are expected to work for. Whereas the consequence of choice responding for non-human subjects is typically a primary reinforcer (e.g., food pellets), human participants generally work for a tokens, or points, that are later exchangeable for another conditioned reinforcer, money (see Buskit & Miller, 1982). Conditioned reinforcers acquire their capacity to reinforce behaviour through their association with other stimuli that are already effective reinforcers (Catania, 1992). However, whereas primary reinforcers are immediately consumable, points are usually converted into money only at the end of the experiment. There is some evidence to suggest that this disparity in experimental design may account for at least some of the differences in humans and non-human behaviour reported in operant studies (Flora & Pavlik, 1992; Jackson & Hackenberg, 1996).

Human participants usually have an extensive history with points, so that points are often presumed to act as reinforcers even in the absence of explicit instructions (cf., Logue et al., 1986; Navarick, 1996). However, the precise role that points play for humans in operant research is a matter for debate. As previously mentioned in chapter 5, Wearden (1988) has argued that points later exchangeable for money have little incentive value but rather function like other informational variables by indicating to participants that their behaviour is appropriate to the experimental demands. This interpretation is only partially supported by the findings of the Experiment 1 (see chapter 5), in particular by the significant interaction between the differential and prospective information variables. The addition of prospective information had no effect on choice when the reward differential was small but it negated the significant decrease in global choices otherwise observed when the differential was large (see Figure 5-6). This suggests that points may not be a powerful enough incentive to overcome the effects of purely cognitive manipulations.

Evidence of this kind raises the possibility that points may not be the most appropriate choice outcome for self-control studies because they seem to have a relatively low incentive power and they are not immediately consumable. On each trial of a self-control experiment using points, although there may be a choice between a SS number of points and a LL number of points (e.g., Solnick et al., 1980), typically the accumulated points are not converted into money until the end of the experiment, and then there is a further delay until the participant can actually spend that money. In some respects, therefore, it is arguable that points cannot provide an immediate reward. As a result, in Experiment 2, the reward dimension under the participants' control was not the number of points that could be earned on each trial but rather the time delay preceding the start of the next trial. In each trial in Experiment 2, the participants scored 1 point but the delay before the next trial began depended on the participants' previous choices. So, whereas in Experiment 1 participants earned a performance related number of points in a session of set duration, in Experiment 2 participants earned a set number of points in a session, but the duration of the session was dependent on performance.

Delay has already been used in studies by Herrnstein et al. (1993), Kudadjie-Gyamfi and Rachlin (1996), and Gray (1999). The aim of this experiment was to further evaluate the use of time delay for future studies and to assess its incentive power by changing the differential between the two alternatives on each trial.

6.2 Method

6.2.1 Design

Participants received 200 successive choice trials between two concurrently available alternatives, A and B. Both A and B delivered 1 point after a delay that varied according to an algorithm (see section 6.2.3). It was assumed that waiting between choices was aversive (boring) for the participants and, therefore, minimising the inter-trial delay was rewarding in itself. To further emphasise the benefits of minimising delay (i.e., faster rate of scoring), the participants were told in their instructions (see section 6.2.4) that they were choosing under a time constraint, and were not informed as to the number of trials that the session would last. However, because each session did consisted of a set number of trials all the participants eventually scored the same number of point regardless of their responses.

The delay incurred through choosing B always remained greater than A by a constant differential amount. This delay differential between the two immediate choices was the independent variable, and was either 3, 5, or 7 s. The experimental design is summarised in Table 6-1. The primary dependent variable was the proportion of B responses made throughout the experiment. In addition, response latencies were recorded on a trial by trial basis.

Table 6-1

Design of Experiment 2

Differential (s)	3	5	7
Group	1	2	3

Following the test, participants completed a short questionnaire (see Appendix B) designed to determine their awareness of the local-global contingencies under which they were choosing.

6.2.2 Participants

Forty-eight female students were recruited from the departmental participant pool. Female participants were used because no males were available from the departmental participant pool. Their ages ranged from 19 to 25, with a mean age of 19.75 years (SD = 1.12). They were randomly assigned to one of the three experimental groups and their participation earned course credit and payment as stipulated in the instructions (see section 6.2.4) that equated to each person being paid £4.00 regardless of performance.

6.2.3 Apparatus

Participants were tested individually in a small cubicle (1.5m by 3m) containing a desk, on which was mounted an Opus Technology P200 PC with a soundcard, a 15 inch SVGA monitor (800 by 600 pixels),.and a Mitsutech USA Corporation touch-screen. The touch-screen was used because several of the participants who took part in Experiment 1 (chapter 5) informally reported a preference for the left mouse button because of its high usage in Windows applications.

The experimental conditions were programmed as a Microsoft Windows 95 application using Borland Delphi 3. The subject interface, shown in Figure 6-1, consisted of the participant's score, displayed numerically in a yellow font in the centre of the screen, and a

5cm diameter, green circle in each of the two bottom corners. The touch screen allowed these two circles to function as buttons through which participants made their choices. The screen was blank during the delay periods and a choice could only be made when the display was visible on the screen.

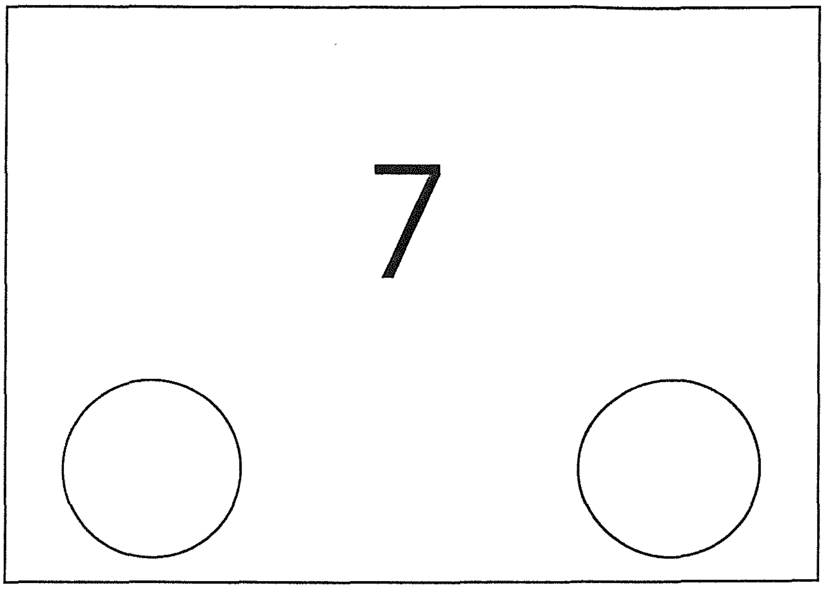

Figure 6-1. Screen display. The number told the participant how many points they had scored, and the two circles denoted the sensitive areas of the touch-screen where the participant could make a response when the screen was visible.

The program instantiated an algorithm for the delay preceding the award of a point for A and B responses. On any trial, the delay incurred on each choice was dependent on the number of previous A responses according to the following rules:

1. A is set less than B by a constant differential value (either 3, 5 or 7 s)
2. Each choice of A incurs a delay of N s
3. Each choice of B incurs a delay of N s plus the differential value
4. N equals the number of times A has been chosen in the previous 10 trials.

Figure 6-2 shows how these rules determine the delay contingent on an A response or a B response as a function of the number of A responses in the previous 10 trials. Repeatedly choosing the quicker alternative (A) will drive up the value of N and thus the delay associated with both alternatives over a series of 10 trials. However, choosing the slower alternative (B) will gradually reduce the value of N and thus in the longer-term the reward rate of both alternatives will gradually increase above that of the initially quicker alternative, A.

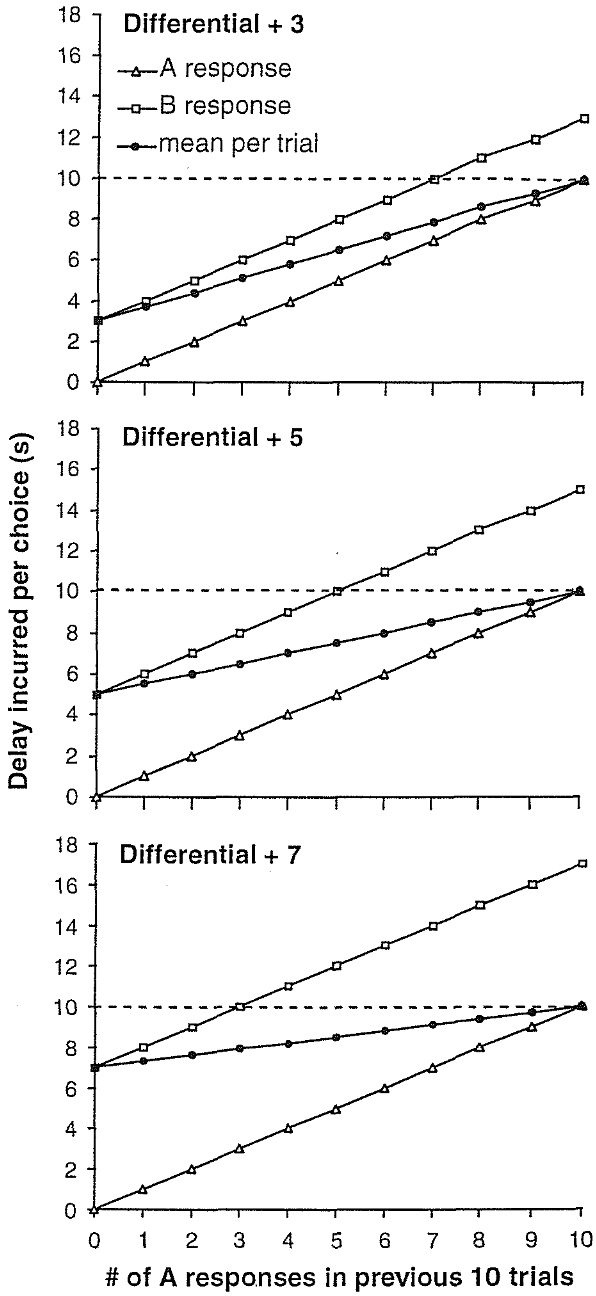

Figure 6-2. Length of delay contingent on an A response or a B response as a function of the number of A responses in the previous 10 trials. The mean line indicates the average delay per trial as a function of the average number of A responses in the previous 10 trials. The dashed line at 10 on the y-axes is provided for visual clarity.

The positive correlation between the proportion of A responses and the total delay incurred over the 200 trials is virtually perfect ($r = .99$; $p < .01$). If A is chosen consistently over the 200 trial the overall delay incurred will be 1970 s (approximately 33 min). In comparison, if B is chosen consistently the overall delay will be 625, 1025, or 1425 s (approximately 10.5, 17, or 24 min) for the differential values of 3, 5, and 7 s respectively. Thus, the algorithm provides maximum overall utility for repeated B (global) responses.

6.2.4 Procedure

Participants were seated individually in front of the computer and asked to read the instructions from a printed sheet. They were also provided with an appropriate printed screenshot (see Figure 6-1). The instructions read as follows:

> Thank you for taking part in this experiment. Please read these instructions carefully and please ask about anything that isn't clear.
>
> The aim of this task is to score points. You will earn 20 pence for every 10 points you score. However, you will only have a limited amount of time in which to score these points, but we can't tell you how long. Points are scored by pressing the left and right buttons on the screen, though you can only press one button at a time. Each time you press one of the buttons the display will blank out for a few seconds. When it reappears, you will receive 1 point and will be able to make your next choice (whether to press the left or right button).
>
> Please look at the diagram of the experimental display at the bottom of this page. The two green circles in the bottom corners of the screen are the buttons which you must press to score points. The number in the centre of the screen represents your score. The participant in this example has currently scored 18 points. You will be able to make your next choice whenever this display is on the screen (i.e., anytime the screen is not blank).
>
> To get you used to the study you will be given 5 practice choices. This trial period doesn't count for anything and does not have any time restrictions. The purpose of this is just to allow you to get used to the display and making your choices. Once you have finished this practice session the machine will reset and you can start the actual task.

Remember, in the actual task, you have a limited amount of time to score as many points as possible and you will be paid 20 pence for every 10 points scored. Please ask if you have any questions. When you are ready, please press the START button.

To the right of the monitor was a sign that read "Please remember that your time on this task is limited. 10 points = 20 p."

A trial began when the display appeared on the computer screen. The participant made a choice by pressing either the left or right button on the screen that led to the display going blank for the delay period. When the display reappeared, one point had been added to the score in the centre of the screen. Response latencies for both A and B responses were measured from the time the display appeared on the screen to the time when a button was pressed. To avoid a possible left/right bias, the function of the response keys was counterbalanced (i.e., half the participants in each group made an A choice on the left button and half made an A choice on the right button). All participants were given 5 warm-up trials to familiarise themselves with the screen display and the controls. During these trials both buttons on the screen delivered 1 point after a delay of 3 s. On completion of the warm-up trials the experimenter left the cubicle.

At the start of the experimental phase of the study the initial value of *N* was 5 and the register of previous choices that determined the value of *N* was pre-set with the sequence 'ABABABABAB'. The participants received 200 trials during which points were awarded according to the algorithm described in the section 6.2.3.

Following the completion of the choice procedure, participants were instructed to fill out a questionnaire designed to assess their explicit knowledge of the algorithm underlying the pattern of point delivery. A different scoring system from that previously reported in Experiment 1 was used. This change was made for two reasons. First, the previous scoring system only produced a moderate level inter-rater reliability, and second, the verbal reports made by the participants under the delay procedure were (subjectively) more vague than those produced following the points procedure. This may reflect the fact that the participants found it more difficult to quantify delay than points. However, in the current study awareness of the contingencies was rated on a simpler binary scale. One of the questionnaire items asked, "If you could only press one button throughout the task which would you press and why?" In answer to this question, if the participant indicated the global button then they were rated as being globally aware, otherwise they were rated as unaware. An assessment was then made from the additional written information as to whether the participant had answered this question based on the schedules of reward or whether their reported preference was based on another factor, for example, the physical location of the buttons.

6.3 Results

The effect of the levels of the differential variable on the mean proportion of B responses is shown in Figure 6-3. A series of one-sample *t* tests revealed that the mean proportions for each of the levels fell significantly below 50% (i.e., indifference between the two available choices), all $t(15) < -2.73$, $p < .05$. Thus, overall there was a greater tendency for participants to choose the larger of the two immediate alternatives.

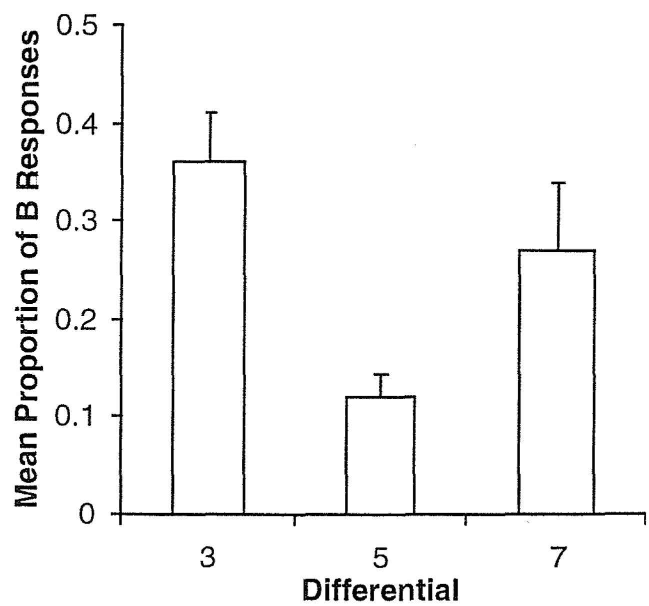

Figure 6-3. Mean proportion of global (B) responses by factor. One standard error is shown above the mean.

To examine the effect of changing the differential value on the overall pattern of choice and the time course of those effects, the 200 trials were divided into 5 blocks of 40 trials (Blocks 1-5). The mean proportion of B responses per block was calculated and a mixed-design ANOVA (Differential × Block) was used to determine main effects and any interaction between the factors. Because the initial analysis, excluding block, violated the assumption of homogeneity of variance, Box's (1954) correction was applied to modify the degrees of freedom and make the test more conservative. Even with this adjustment, there was a significant effect of differential, $F(1, 15) = 6.00$, $p < .05$. Post-hoc analysis using the Games-Howell test, which does not assume equal variances, revealed only one significant difference. Those choosing with a differential of 3 s chose significantly more B choices than those with a differential of 5 s.

The mixed-design ANOVA was also used to determine whether there was a main effect of block and any interaction between block and the differential. The mean proportion of B responses per block for each condition is shown in Figure 6-4. As the data violated the assumption of homogeneity of covariance the Greenhouse-Geisser correction was used to modify the degrees and make the test more conservative (see Howell, 1997). The results showed a significant main effect of block, indicating a gradual decrease in the proportion of B responses as the session progressed, $F(1, 45) = 7.29$, $p < .05$. However, the interaction between block and the differential was not significant, $F(2, 45) = 3.10$, $p = .55$.

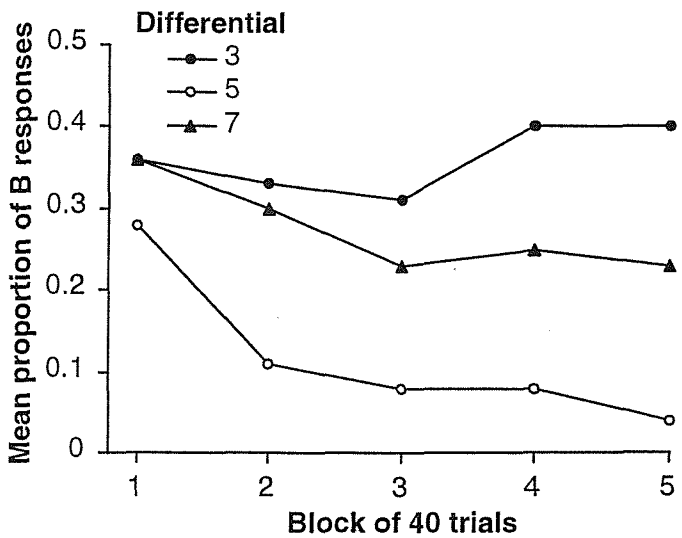

Figure 6-4. Mean proportion of global (B) responses per block of 40 trials shown for each level of the differential variable.

Although generally considered to be fairly robust, as the data violated both the assumptions of normality and homogeneity of variance it is arguable whether ANOVA was a suitable statistical test (Howell, 1997). For this reason, a non-parametric equivalent to the ANOVA, the Kruskal-Wallis test was also used to compare the groups. The result confirmed the difference between the groups, $H = 8.55$, $p < .05$. Subsequent Mann-Whitney U tests confirmed the finding of the parametric analysis, in that there was only a significant difference between groups with the differential values of 3 and 5, $U = 51.0$, $p < .05$, and not between 3 and 7 or between 5 and 7.

The post-experimental questionnaire showed that the participants' awareness of the algorithm underlying variation in the reward delays was generally poor. Few of the participants (2/48, 4%) were rated as having understood the experimental conditions while the majority (43/48, 90%) were rated as having no knowledge of the rules. Spearman's test of rank correlation showed no significant correlation between rule knowledge and the proportion of B responses made. Of those rated as having no knowledge of the rules, 15 (35%) reported that they based their choices on the physical characteristics of the apparatus (e.g., the locations of the two buttons relative to the participant's dominant hand) rather than the delays they produced. Of these 15, 9 were in the differential 3 s group, 2 were in the differential 5 s group, and 4 were in the differential 7 s group. A chi-squared test showed that this distribution was significant, $\chi^2(2, N = 48) = 7.56$, $p < .05$.

Response latencies for each participant were collated into 5 blocks of 40 trials and the mean latency per block for each condition calculated. A mixed-design ANOVA (Differential × Block) was used to determine whether there was any main effects or interactions between the factors. The analysis showed that differential had no effect on response latencies. However, incorporating the Geisser-Greenhouse correction, the analysis revealed a significant main effect of block, $F(1, 45) = 11.79$, $p < .05$. The mean response latencies for each block are shown in Figure 6-5. A visual inspection of the data suggested a decrease in response latencies between Block 1 and Block 2, and a paired t test found this difference significant, $t(47) = 4.51$, $p < .05$.

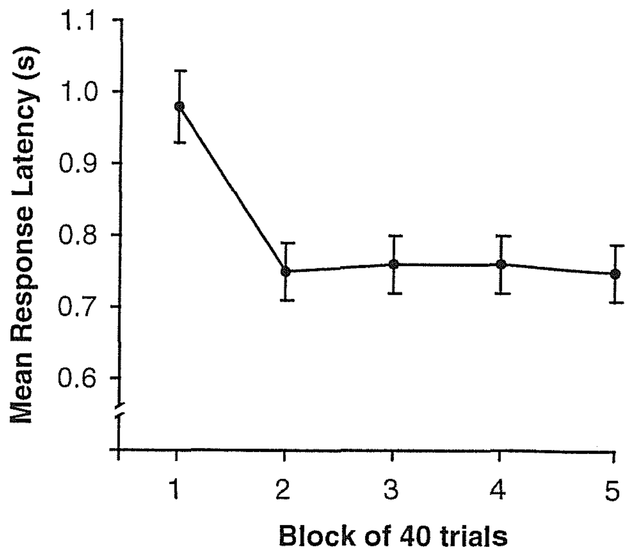

Figure 6-5. Mean Response Latency by Block of 40 choices. One standard error is shown above and below each point.

The raw data from this experiment are presented in Appendix C.

6.4 Discussion

The results of Experiment 2 suggest that the participants were relatively insensitive to the global contingencies in varying delay. There was a strong tendency to choose the shorter of the two immediate delays despite the fact that, over the entire session, choosing the immediately longer delay would have been more beneficial in terms of minimising the overall session duration (maximising the global outcome). These pattern of results are not unlike the findings of Experiment 1 and previous studies (e.g., Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996). In Experiment 1 it was found that, when number of points was the dimension under the participants' control, the basic effect could be moderated by incentive. Generally, those participants who were exposed to a larger incentive (i.e., larger differential) to choose the immediately rewarding alternative performed worse in terms of maximising global reward. Although the current study used delay rather reward points are the reward dimension, it was reasoned that manipulating the local incentive by changing the differential would produce comparable effects to Experiment 1. However, although there was a significant decline in global choices between the group experiencing a differential of 5 s as compared to those in the 3 s condition, the proportion of global choices made by participants with a 7 s differential did not statistically differ from either of the other two groups. Although this result was not the straightforward linear relationship predicted between differential and choice, the evidence nevertheless indicates that the experimental manipulation of delay affected the choice made by the participants.

Suboptimal choice occurs within this paradigm because, (1) the participant is unaware that current choices affect the subsequently available outcomes so that the immediately better (local) alternative does not maximise global reward, or (2) given awareness, the incentive to choose the immediate reward outweighs the temporally discounted value of the global reward (Herrnstein et al., 1993). The current procedure required participants to make two temporal discriminations in order to achieve awareness. The first discrimination involved the differential between the two currently available alternatives, in this experiment either 3, 5, or 7 s. The second, more subtle discrimination, involved the change in both delays between successive trials. This change was determined by the value of *N* that, depending on the preceding choice (A or B), either increased or decreased by 1 s, or remained unchanged.

The design for this experiment assumed, perhaps naively, that participants would be sensitive to immediate differences in delay resulting from the two buttons, even if they were insensitive to the changes in delays between trials and the implications for global reward. However, the distribution of choices and the verbal reports collected in the questionnaire suggest that a sizeable proportion (15, 31%) of the participants failed to detect even the local differences between the two alternatives, and reportedly based their responses on the physically characteristics of the apparatus (i.e., the positioning of the buttons behind the touch screen).

Sensitivity to changes in stimuli is the province of psychophysics. The psychophysical principle, Weber's law, states that when comparing temporal intervals, the increase in duration required to produce a just noticeable difference is a constant proportion of the initial stimulus (see Getty, 1975, 1976; Sekuler & Blake, 1994). It is likely, therefore, that the linear relationship between previous choices and future rewards may have made the temporal discriminations more demanding. As the value of *N* increased, any difference in delay between subsequent trials, either resulting from a change to the other response key (i.e., the differential) and / or the value of *N* changing, would become proportionally smaller. This is exemplified in Figure 6-6, that illustrates temporal discriminations at the extreme values of *N*. A differential of 3 s constitutes 75% of the delay incurred following a B response when *N* is 1 s, but only 23% of the delay when *N* is 10 s. Also, the change from an A to a B response on subsequent trials represents a 300% increase in delay when N is 1, but only a 30% increase when N is 10.

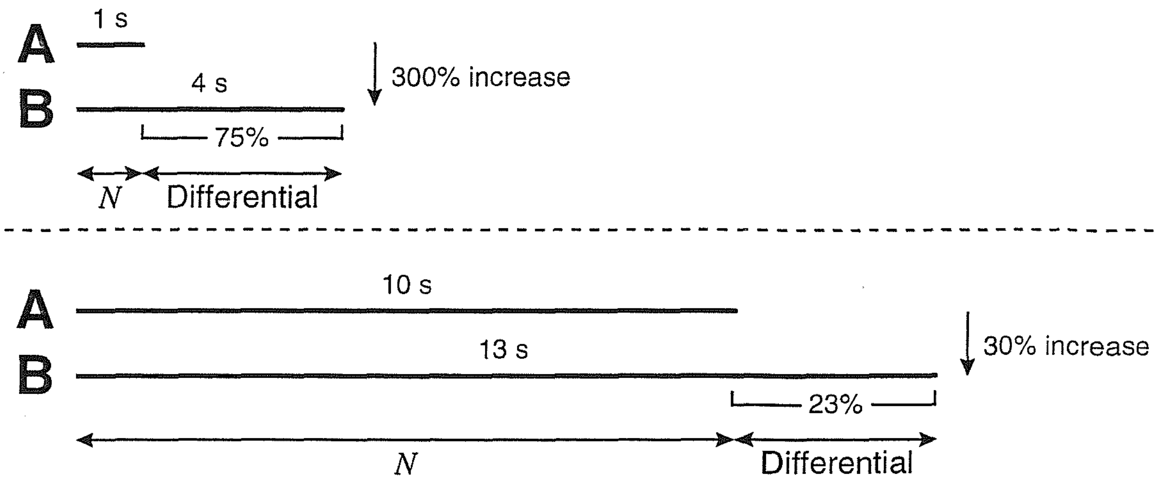

Figure 6-6. Illustration of the extreme temporal discriminations that participants may have experienced.

Whether the participants' ability to detect changes in duration was a factor in the results produced by this experiment is unclear. The fact that a significant number (9) of the participants who reported no local differences in delay were in the 3 s differential condition would seem to support the conclusion that small changes in delay were not easily detectable. However, the fact that all three groups exhibited a significant preference for the immediately more valuable local choice (A) would seem to indicate that participants were sensitive to the differential. It would seem a reasonable possibility that the results of this experiment reflect an interaction between delay sensitivity and the experimental demands on the participant to behave appropriately. When the differential was small, discrimination between the two potential outcomes was difficult and so the proportion of choices tended towards indifference. When the differential was large, the immediate difference between the two potential outcomes was obvious, but perhaps this made the participants perceive the shorter delay as "too much of a good thing", and so they were more prepared to examine the other alternative. Nevertheless, determining the participants' sensitivity to changes in delay was beyond the scope of the present research, but it is a factor that warrants consideration for future research.

Interestingly, both Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996) used delay in their studies and reported no problems with their participants' ability to detect small changes in time, despite the delays in question being of similar duration. However, the current procedure differed from both these previous studies by virtue of the fact that previous researchers may have (fortuitously) negated the problem of temporal perception by providing their participants with additional verbal information regarding the length of the current delay. On each trial, Herrnstein et al. displayed a graphical representation of a coin that moved at regular intervals down the computer screen while Kudadjie-Gyamfi and Rachlin presented a digital clock that counted down the period between choices. Unfortunately, neither of these groups of researchers justified the inclusion of these design features, and a similar feature was not included in the current experiment because it was originally felt that such additional information would make the global contingency too obvious. However, if differences in delay are not detectable, so that the participants perceive both alternatives to be equal, then there is no basis for talking about the participants' preferences based on the contingencies. Indeed, as discussed in chapter 1 (see section 1.2), impulsiveness and self-control are typically only used to describe behaviour if the different outcomes are recognised. Therefore, if time is to be used in further research it would seem sensible to provide some form of information that can assist participants in comparing duration and changes in delay.

Another factor that should be considered, is the way in which the choice outcomes are framed in terms of either gains and losses. Prospect theory, a descriptive model of choice under risk, suggests that humans are more sensitive to losses than they are to gains (Kahneman & Tversky, 1979; Thaler, Tversky, Kahneman, & Schwartz, 1997; Tversky & Kahneman, 1992). An experiment by Herrnstein et al. (1993), reviewed in chapter 3, directly compared framing in terms of loss and gain within the current choice paradigm. The findings of this study seemed to support the assertion that participants are more sensitive to loss. Although only marginally significant, participants made a higher proportion of global choices when the task was framed in terms of losing money than when it was framed as gaining money. Considering the poor performance in terms of global maximisation of the present experiment, future research may benefit by framing the task in terms of loss as opposed to gain.

Overall, the results of this study, although inconclusive, seem to support Herrnstein et al.'s (1993) assertion that perception of the global contingency is a requirement for global maximisation (self-control). However, this study has also served to highlight several methodological problems that need to be addressed in the design of future studies.

Chapter Seven - Effects of Rate of Change and the Provision of Delay Information

7.1 Rationale

Failure to maximise reward in the choice procedure developed by Herrnstein, Prelec and Vaughn can be explained in terms of either cognitive or motivational factors (Herrnstein et al., 1993). Cognitive factors affect a participant's awareness that current choices have consequences for the magnitude of subsequent rewards. Awareness is considered a prerequisite for maximisation. Motivational factors concerned the possibility that, despite awareness of the global contingency, suboptimal choice may still occur if the incentive to choose the immediately larger reward is too great. Such suboptimality is commonly attributed to temporal discounting, the depreciation of the current utility of a reward as a function of the time until its delivery (Ainslie & Haslam, 1992). Assuming hyperbolic discount functions, the value of a large, future reward may drop below that of a smaller, but more immediate reward. This latter explanation fits well with the intuition that in everyday life people often behave impulsively despite knowing that in so doing they are not acting in their own best interests.

The first study of this thesis (chapter 5), and the studies detailed in chapter 3 (Gray, 1999; Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996), demonstrated that humans are relatively insensitivity to the contingencies of global choice. In most cases, participants tended to select the more valuable of the two immediate alternatives, thus failing to maximise potential reward. Primarily, these studies have focused on cognitive factors, attempting to assess how performance is affected by manipulations that increase the participants' awareness of the extended temporal nature of the situation. In Experiment 1, performance was found to improve when participants were explicitly shown the values of the two current choices (i.e., prospective information) and allowed to periodically compare their score with the optimum score at that time (i.e., social comparative information). Similarly, Kudadjie-Gyamfi and Rachlin (1996) found participants made more global choices when choices were grouped together in discrete blocks. These factors can be interpreted as cognitive because, in different ways, each enhances participants' awareness that current choices have consequences for future rewards.

Arguably the most efficient way to increase the salience of the global contingency is to provide explicit information in the form of verbal rules. Herrnstein et al. (1993) studied the effects of offering participants hints, of varying explicitness, regarding the optimal strategy. The clearest hints, indicating the optimal strategy, increased preference for global choices, but participants still failed to maximise. Kudadjie-Gyamfi and Rachlin (1996), however, failed to find any improvement in performance when they provided explicit hints. In contrast to providing a verbal basis for rule-making prior to the procedure, Experiments 1 and 2 attempted to assess participants' awareness of the contingencies on completion of the task using a questionnaire. The findings showed that although only a few participants (7 / 112, 6%) were rated as having the highest level of understanding of the rules, there was a positive correlation between awareness and the proportion of global choices made.

To a lesser extent, the impact of motivational factors on choice has also been investigated. For example, in Experiment 1, it was found that preference for immediate reward was increased when the differential between the two immediate choices was large. However, possibly the most important motivational component of this task is the nature of the rewards offered. In Experiment 1, participants were invited to choose between points that were exchangeable for money at the end of the study. However, because it has been argued that points have little real incentive value for human participants in operant research (e.g., Wearden, 1988), the use of points was abandoned and, in Experiment 2, the delay preceding the next choice point was adopted as the reward dimension. However, although the use of delay had been successful in studies by Herrnstein et al. (1993) and Kudadjie-Gyamfi and Rachlin (1996), the results of Experiment 2 were inconclusive. It was suggested that this failure may have resulted from the participants inability to discriminate small changes in delay between trials. To compensate for this possibility it was proposed that verbal information (e.g., a clock) regarding the length of delay be included in future experiments.

Another motivational factor that needs to be considered is the framing of the task in terms of loss or gain. Prospect theory (Tversky & Kahneman, 1992) suggests that participants are more sensitive to losses than they are to gains, and this has been at least partially supported in the current choice procedure by Herrnstein et al. (1993). In Experiment 2, although the critical dimension that was dependent on the participants' responses was the length of the delay between trials, the task was framed in terms of the participants gaining money. Due to the poor performance of the participants in Experiment 2, further research may benefit by framing the task in terms of loss.

Results from earlier studies clearly show that cognitive factors that improve the salience of the global contingency facilitate maximisation. However, some of the factors previously studied may have been ineffective because the manipulations were too subtle for the participants to detect. For example, Herrnstein et al.'s (1993) third experiment (see chapter 3) may have suffered from the same problem of temporal discrimination that may have afflicted Experiment 2. In Herrnstein et al.'s study, participants were required to choose between different delays while under a time constraint to earn money. One of the factors studies was the rate at which the delays increased and decreased depending on the participants' previous choices. For some of the participants, the incremental changes in delay that could occur between trials were less than 0.5 s, and arguably these changes were too difficult to detect.

The present study was designed to resolve two issues. Firstly, to determine whether increasing the rate of change, as previous done by Herrnstein et al. (1993), improved performance by making the global contingency more salient. And secondly, but related, to determine whether the participants' failure to maximise global reward in Herrnstein et al's experiment and in Experiment 2 of this thesis resulted from the participants' lack of sensitivity to changes in delay. This was accomplished in two ways. The rate of change was varied between participants, and the changes in delay were greater than those previously used by Herrnstein et al. so that they would be easier for the participants to perceive. Furthermore, half the participants were provided with explicit delay information (a clock) regarding the duration of the current delay. It was reasoned that awareness of the global contingency should be greatest in the condition with a greatest rate of change and explicit delay information, and that this would be reflected in participants making a greater proportion of global choices.

7.2 Method

7.2.1 Design

The participants' task was to minimise the duration of the experiment because so doing would maximise earnings. They received 80 successive choice trials between two concurrently available alternatives, A and B. Both A and B responses produced a delay before the next choice could be made, though the delay incurred through choosing B always remained greater than A by 5 s. The delays generally increased following an A response and decreased following a B response (see section 7.2.3). The amount of money that participants received on completion of the 80 trials was dependent on a gradually diminishing pool of money, that decreased at a constant rate throughout the experimental session. Thus, the amount of money received by a participant was inversely proportional to the total delay accumulated over the session. The primary dependent variable was the proportion of B responses made throughout the experiment. In addition, response latencies were recorded on a trial by trial basis.

The experiment used a 3 x 2 nested factorial design to investigate the effects of two independent variables on the proportion of B responses and response latencies. For all conditions, the delay incurred through an A response was between 0 and 24 s (5 and 29 s for a B response). The first independent variable was the rate at which the delay changed as a result of the previous choices. Because the minimum ($N_{(Min)}$) and maximum values ($N_{(Max)}$) of the delay were constant across conditions, rate of change was defined by two mutually dependent parameters, the increment size (I) and the averaging window (W), as shown in Equation 7-1 (for derivation, see section 4.2.1).

$$I = \frac{\left(N_{(Max)} - N_{(Min)}\right)}{W} = \frac{24}{W} \qquad (7\text{-}1)$$

The three levels of rate of change were increments of either 2 s with an averaging window of 12 trials, 4 s with an averaging window of 6 trials, or 6 s with an averaging window of 4 trials. The second independent variable was the presence or absence of explicit delay information during the delay period. The experimental design is summarised in Table 7-1.

Table 7-1

Design of Experiment 3

Delay Information	No			Yes		
Rate of Change (s × window)	2×12	4×6	6×4	2×12	4×6	6×4
Group	1	2	3	4	5	6

Following the test, participants completed a short questionnaire (see Appendix B) designed to determine their awareness of the experimental conditions.

7.2.2 Participants

Sixty 1st and 2nd year undergraduate psychology students (10 males and 50 females) were recruited from the departmental participant pool. Their ages ranged from 18 to 34 years, with a mean age of 19.6 years (*SD* = 2.6). Participants were randomly assigned to one of the six experimental groups and were paid as stipulated in the instructions (see section 7.2.4).

7.2.3 Apparatus

Participants were tested individually in a small cubicle (1.5m by 3m) containing a desk, on which was mounted an Opus Technology P200 PC with a soundcard and a 15 inch SVGA monitor (resolution: 800 by 600 pixels). The experimental conditions were programmed as a Microsoft Windows 95 application using Borland Delphi 3. The subject interface, illustrated in Figure 7-1, consisted of two main parts. At the top of the black screen was the display keeping a running total of the amount of money the participant would be paid at the end of the 80 trials. This started at £6.00 and steadily decreased at the rate of 1p every 4.25[3] s. The gradual erosion of the size of the payment was emphasised by a moving graphic showing a series of coins slowly dropping from the money display into a bin in the centre of the screen. Each time a coin reached the bin, 1p was removed from the sum of money and the next coin began its descent. At the bottom of the screen were two green, square buttons that participants could select using the mouse cursor. The use of a touchscreen, as in Experiment 2, was abandoned because one third of the participants reported in the post-experimental questionnaire that their responses were based on the physical characteristics of the apparatus, specifically the location of the buttons. The use of the mouse combined with the on-screen buttons was felt to be a suitable alternative that negated the participants' reported preference for the left mouse button in Experiment 1 and the button closest to the participants' dominant hand in Experiment 2.

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[3] Earnings were originally designed to decrease at 1 p every 4 s but, due to an unforeseen lag caused by a programming loop, the actual rate of decline was marginally slower (1 p every 4.25 s).

At the start of each trial, both buttons were green and the cursor was centred between them. Following a choice, for the duration of the delay period the chosen button became black with a green outline while the other button was removed temporarily. During the delay period, participants in the explicit delay information condition saw a digital clock displayed between the two buttons that counted down the number of seconds delay to the next choice point.

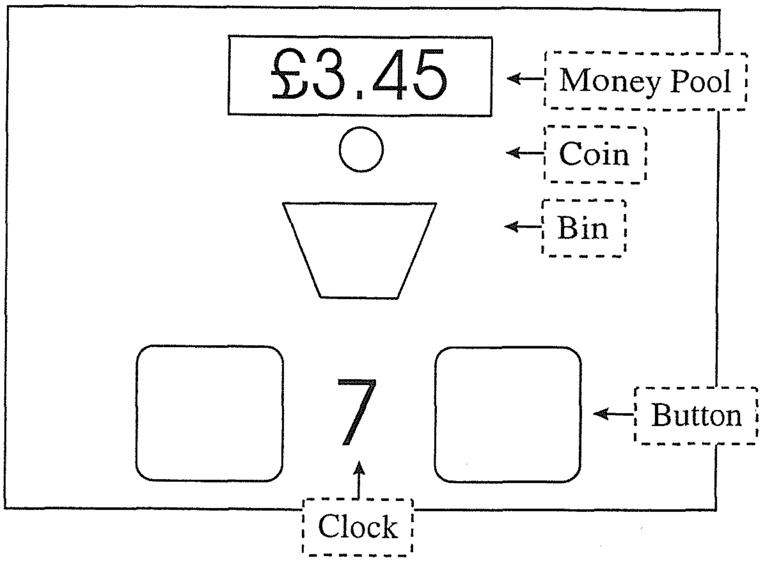

Figure 7-1. Screen display. This display told participants when they could choose and how much money they would earn at the end of the session. The clock, that countdown the time before the next choice could be made, was only present in the explicit delay condition.

When a button was selected the program instantiated an algorithm for the delay preceding the next choice point. On any trial, the delay incurred on each choice was dependent on the number of previous A responses according to the following rules:

1. Each choice of A results in a delay of N s.
2. Each choice of B results in a delay of ($N + 5$) s.
3. N equals the size of the increment, either 2, 4, or 6, respectively multiplied by the number of A responses in the previous 12, 6, or 4 trials. Thus, the maximum value of N was 24 for all conditions, although the rate of change varied depending on the size of the increment.

Figure 7-2 shows how these rules determine the delays contingent on an A response or a B response as a function of the number of A responses in the previous trials. It also indicates the average delay incurred per trial as a function of the average number of A responses in the averaging window over the session.

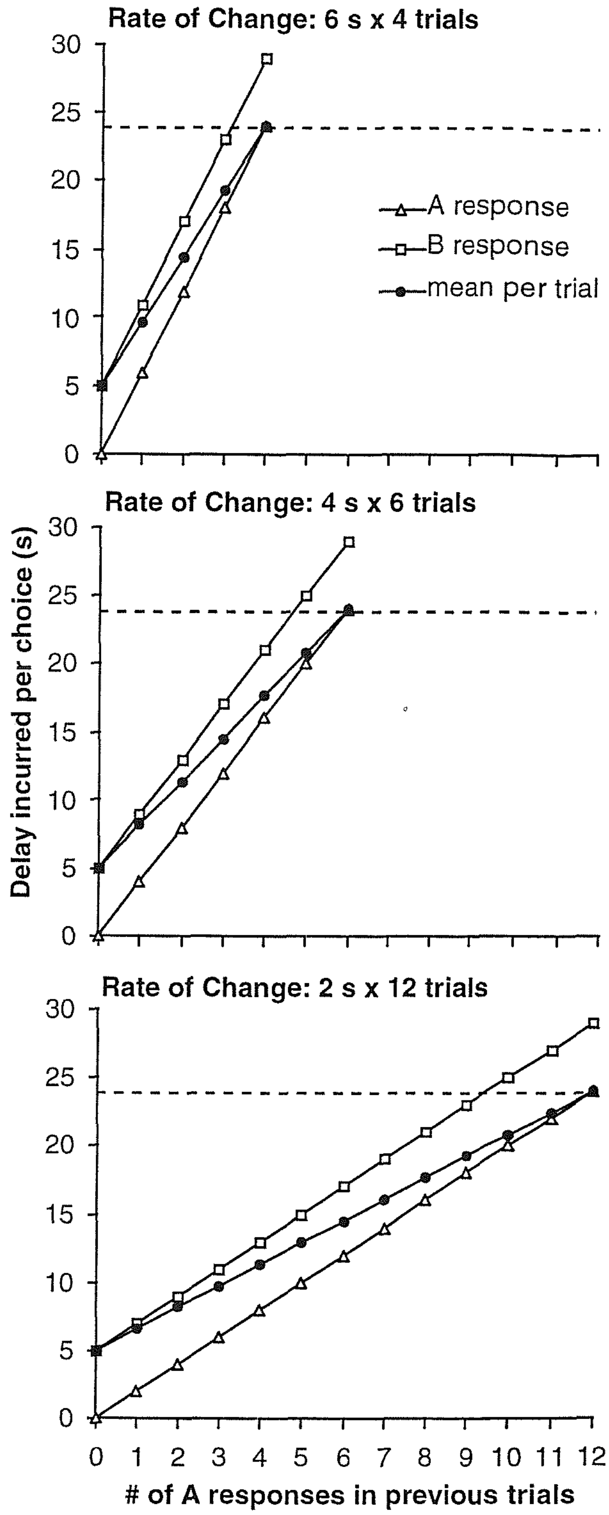

Figure 7-2. Length of delay contingent on an A or a B response as a function of the number of A responses in the preceding trials. The number of previous trials that affects the current outcomes is dependent on the rate of change. The mean line indicates the average delay per trial as a function of the average number of A responses in the averaging window. The dashed line at 24 on the y-axes is provided for visual clarity.

In each condition, repeatedly choosing the shorter delay (A) drives up the value of N and thus, over a series of trials, the delay associated with both alternatives. Choosing the longer delay (B) reduces the value of N and thus in the longer-term the delay incurred as a consequence of the alternatives declines below that of the initially better alternative, A. The algorithm thus provides maximum overall utility for repeated B choices despite the fact that, on any given trial an A response results in a shorter delay. Theoretically, for each level of the rate of change variable the positive correlation between the number of B choices and the amount of money earned is virtually perfect ($r = .99$). Table 7-2 shows the outcomes in terms of delay and money earned associated with consistent A and B choices for each level of the rate of change.

Table 7-2

Total delay and earnings resulting from consistent A or B responses over the 80 trials

	Rate of change (s × trials)		
Outcome	2 × 12	4 × 6	6 × 4
Delay (s)			
A response	1836	1872	1884
B response	472	436	430
Earnings (p)			
A response	168	160	157
B response	489	497	499

7.2.4 Procedure

Participants were seated individually in front of a computer and asked to read the following instructions from a printed sheet. They were also provided with a printed screenshot (similar to Figure 7-1). Apart from the clause in italics, that was only included for the explicit delay information groups, the instructions read as follows:

Thank you for taking part in this study. Please read the following instructions carefully and ask about anything that isn't clear.

Look at the screenshot in front of you. At the top of the screen is a pool of money, which slowly decreases as time passes. This is shown graphically by coins slowly dropping from the pool into the bin in the centre of the screen. Each time the coin falls into the bin you will lose 1 penny. The pool starts at £6.00, and at the end of the experiment you will be paid whatever sum remains.

The experiment requires you to make 80 choices between two buttons. The buttons are the green squares located at the bottom of the screen. You operate them through the mouse cursor and the left mouse button. Each time you select one of the buttons both will blank out for a number of seconds *and a counter will appear in the area between the buttons showing you how long you will have to wait until the buttons reappear*. When the buttons reappear you will be able to make your next choice (whether to press the left or the right button).

To get you used to the task you will be given 5 practice choices. The purpose of this is simply to allow you to get used to the display and making your choices. This trial period doesn't count for anything and the machine will reset before you start the actual task.

Remember, in the actual task the amount of money you will earn decreases over time. Please ask if you have any questions. When you are ready, please click the mouse cursor on the start button.

A trial began when the green buttons appeared at the bottom of the screen. The participant made a choice by clicking the mouse cursor on either the left or right button on the screen. The chosen button became black with a green outline while the other button disappeared. After the incurred delay, the next trial began and both buttons reappeared. Response times for both A and B choices were measured from the time the buttons appeared on the screen to the time when a button was pressed. To avoid a possible left / right bias, the function of the response keys was counterbalanced (i.e., half the participants in each group made an A choice on the left button and half made an A choice on the right button). All participants were given 5 warm-up trials to familiarise themselves with the screen display and the controls. During these trials both buttons produced a delay of 3 s. On completion of the warm-up the experimenter left the cubicle.

At the start of the experimental phase of the study the register of previous choices that determined the value of *N* was pre-set with a sequence of alternating A and B so that in all conditions the initial value of *N* was 12. The participants received 80 trials during which inter-choice delay varied according to the algorithm described in the Apparatus section. Following the completion of the choice procedure, participants were instructed to fill out a questionnaire designed to assess their awareness of the algorithm underlying the pattern of point delivery. The scoring system for this questionnaire is described in chapter 6, section 6.2.4.

7.3 Results

The effect of the independent variables on the mean proportion of B responses made throughout the testing period is shown in Figure 7-3.

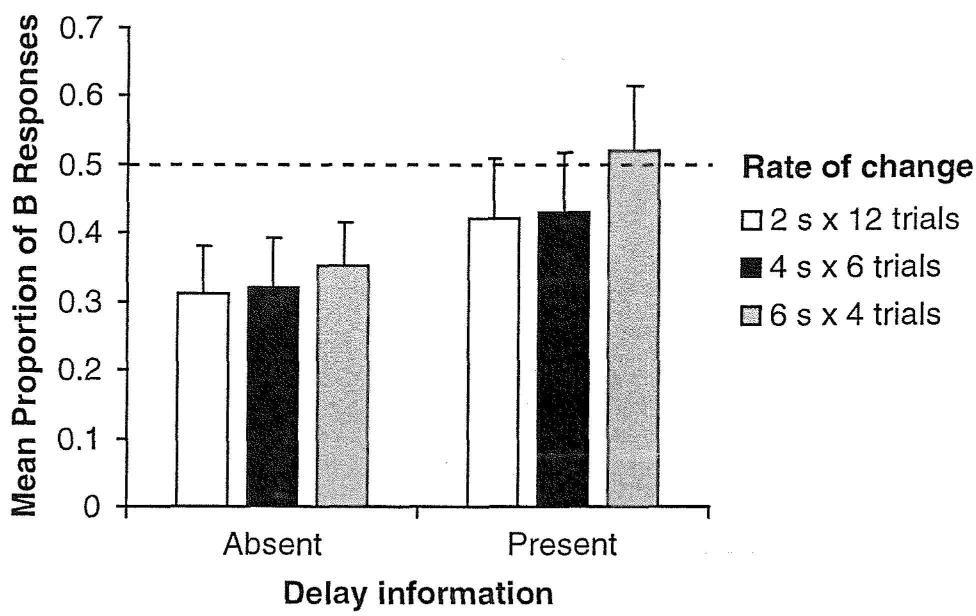

Figure 7-3. Mean proportion of global (B) responses by factor. One standard error is shown above the mean. The dashed horizontal line at 0.5 signifies choice indifference.

To examine the effect of the two key variables on the overall pattern of choice, and the time course of those effects, the 80 choices were divided into 4 blocks of 20 trials (Blocks 1-4). Figure 7-4 shows the proportion of B responses per block made by the participants in each condition.

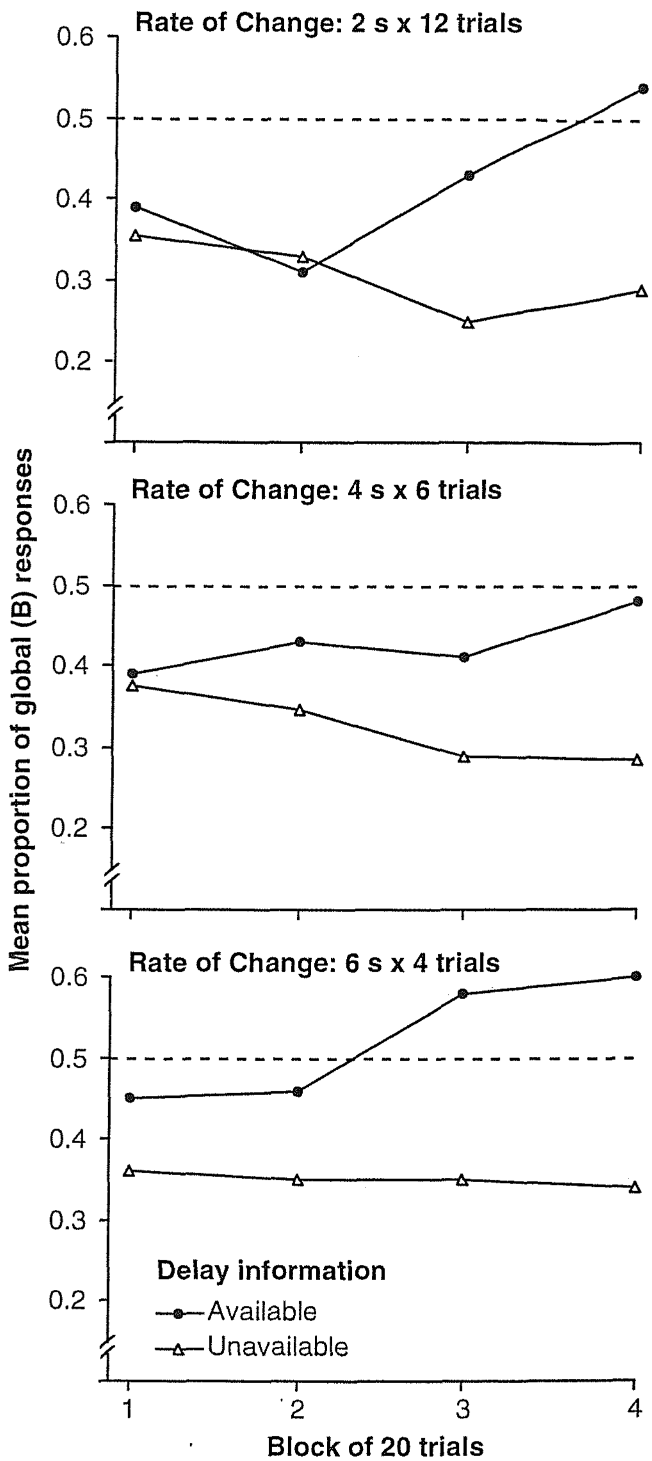

Figure 7-4. Mean proportion of global (B) responses per block of 20 trials shown for each group. The dashed line marked at 0.5 on the y-axes denotes choice indifference between the two alternatives.

The mean number of B choices per block was calculated and a mixed-design ANOVA (Rate of Change × Delay Information × Block) was used to determine main effects and any interactions between the variables. The initial analysis, excluding block, showed no main effects and no interaction between the two variables, although the increase in the proportion of B responses following the provision of the delay information was approaching statistical significance, $F(1, 54) = 3.69$, $p = .06$. However, the rate of change had no significant effect on the overall proportion of B responses, $F(2, 54) = 0.45$, $p = .64$, and there was no interaction between rate of change and delay information, $F(1, 54) = 0.11$, $p = .90$. With block included in the ANOVA, the data violated the assumption of homogeneity of covariance and so the Greenhouse-Geisser correction was used to modify the degrees of freedom and make the test more conservative (see Howell, 1997). The analysis showed that although there was no main effect of block, there was an interaction between block and delay information, $F(2, 113) = 4.00$, $p < .05$. This interaction is shown in Figure 7-5. Further analysis using paired t tests, showed that the provision of delay information had no effect on the proportion of B responses made during Blocks 1 and 2 but produced significantly more B choices during Block 3 and Block 4, $t(58) = 2.10$ and 2.44, respectively, $p < .05$.

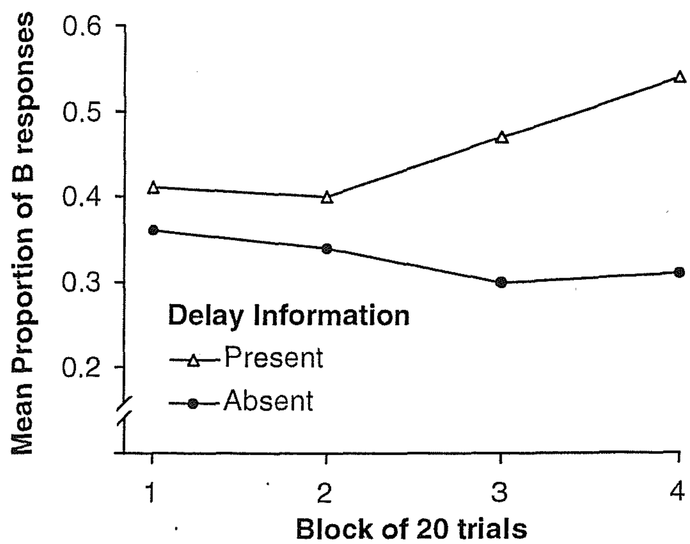

Figure 7-5. Mean proportion of global (B) responses per block of 20 trials shown for conditions with explicit delay information present and absent.

Because only the provision of explicit delay information had an effect on the allocation of choices over time, the group data was collapsed into the two levels of this factor. The mean overall proportion of B responses made by those without explicit delay information was .33 (*SD* = .20) and those with explicit delay information was .45 (*SD* = .29). One-sample *t* tests were used to determine whether these overall proportion of B choices were significantly different from .5 (i.e., indifference between the two alternatives). The result showed that those without explicit delay information chose significantly below the indifference point, $t(29) = -4.85$, $p < .05$, whereas those with the explicit delay information were not significantly different, $t(29) = -0.87$, $p > .05$.

The postexperimental questionnaire asked the participants which button they would select if they had to consistently press the same button throughout the session, and to provide justification for their answer. A third of the participants ($n = 20$) reported that they would chose the global (B) button, and 17 of that group (85% of the subgroup of 20, or 28% of the total participants) provided a reason that demonstrated awareness of the underlying contingencies (as operationally defined). The 3 remaining participants chose the global button but gave reasons that were unrelated to the rules (e.g., based on the physical location of the buttons). The majority of the participants (40, 67%) said they would press the local button continuously and exhibited no awareness of the global contingency. Figure 7-6 shows the proportion of B responses per block depending on the level of awareness demonstrated in the questionnaire. Owing to the fact that these data violate the assumption of homogeneity of variance and the sample sizes are unequal it is inappropriate for analysis using parametric tests. However, a Mann-Whitney *U* test showed that the 17 globally aware participants made significantly more B choices over the 80 trials ($M = .72$, $SD = .15$) compared to the unaware participants ($M = .26$, $SD = .15$), $U = 14.00$, $p < .05$. A chi-squared test showed that there was a relationship between knowledge and the presence of explicit delay information, $\chi^2(1, N = 60) = 9.93$, $p < .05$. Of the 17 globally aware participants, 14 (82%) were in a condition that provided explicit delay information, whereas of the remaining 43 participants, who were not globally aware, only 16 (37%) were in an explicit delay information condition.

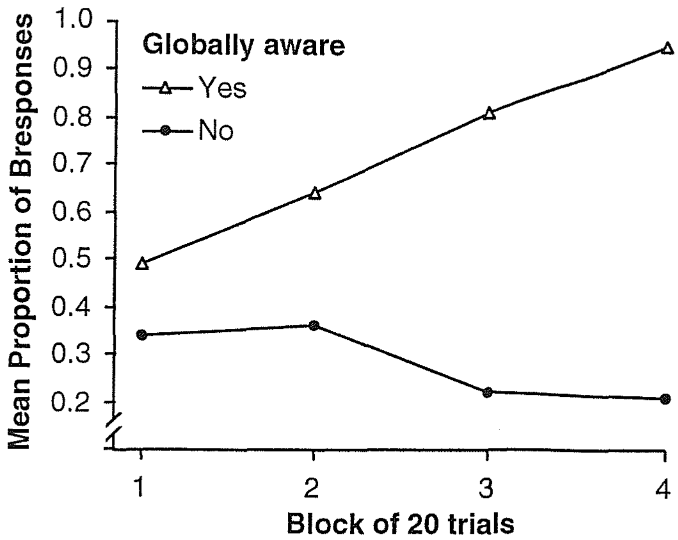

Figure 7-6. Mean proportion of global (B) responses per block of 20 trials shown for the participants who demonstrated global awareness (n = 17), and those who did not (n = 43), in the postexperimental questionnaire.

The response latencies were collated for each participant. Again the 80 choices were divided into 4 blocks of 20 trials (Blocks 1-4) and the mean response latency per block for each condition calculated. A mixed-design ANOVA (Rate of Change × Delay Information × Block) was used to determine whether the independent variables had an effect on the latency. The initial analysis revealed a significant main effect of delay information, $F(1, 54) = 9.73$, $p < .05$, which is shown in Figure 7-7. The mean response latency was reduced when explicit delay information was available to the participants. Rate of change did not have an effect on latency, $F(2, 54) = 0.24$, $p = .78$. The analysis, incorporating the Greenhouse-Geisser correction, also showed a significant main effect of block, $F(2, 95) = 7.78$, $p < .05$. Analysis of the main effect of block using paired t tests showed a significant decrease in response latencies between Block 1 and Block 2, $t(59) = -2.48$, $p < .05$, but no further change between the subsequent blocks.

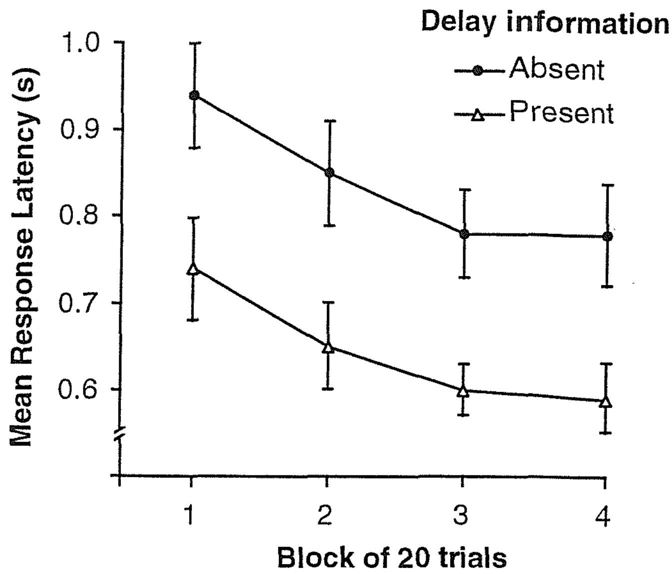

Figure 7-7. Mean response latencies per block of 20 trials for conditions with explicit delay information present and absent. One standard error is shown above and below each point.

Because awareness of the global contingency was found to be associated with improved performance, the relationship between awareness and latencies was also examined. A t test was used to determine whether there was any difference in the mean response latencies of those participants rated as globally aware (n = 17, M = 0.62 s, SD = 0.19) and those rated as unaware (n = 43, M = 0.79 s, SD = 0.26). The t test showed that the response latencies of the globally aware participants were significantly shorter then the unaware participants, $t(58) = 2.40$, $p < .05$. However, overall there was no significant correlation between mean response latency and the proportion of B responses made, $r = -.23$, $p = ns$.

The raw data from this experiment are presented in Appendix C.

7.4 Discussion

Consistent with the previous studies investigating choice under the Herrnstein procedure, participants were generally insensitive to the global contingency and thus failed to maximise financial reward. There was a strong tendency for participants to choose the quicker of the two immediate alternatives despite the fact that choosing the slower would have been more beneficial in terms of maximising global reward (i.e., minimising global delay). Analysis using ANOVA revealed that the proportion of global responses made during the entire session was not affected by either altering the rate of change or providing explicit delay information on each trial. This lack of effect would seem to suggest that neither factor improved the salience of the global contingency. However, when the sessions were analysed in terms of trial blocks, the analysis showed that those participants provided with the explicit delay information made significantly more global responses in the latter half of the session than those without this information (see Figure 7-5). Overall, the proportion of global responses made by those provided with the explicit delay information did not differ from chance levels (i.e., 50-50). In comparison, when explicit delay information was not provided the proportion of global responses made was significantly below chance. This suggests that, in the absence of the delay information, participants chose on the basis of local maximisation.

Because awareness of the global contingency is considered a prerequisite for global maximisation (Herrnstein et al., 1993), the participants' knowledge of the schedules was assessed by questionnaire. Analysis of these self-report data revealed that less than a third of the participants (28%) identified that the immediately poorer alternative led to greater overall reward and could justify their answer by providing a verbal description of the global contingency. The majority (67%) expressed a preference for the local reward and exhibited no knowledge of the global contingency. These findings are similar to levels of awareness expressed by the participants in both Experiments 1 and 2, and in the previous research that has examined verbal protocols (Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996). Those participants who demonstrated global awareness post-session chose the immediately longer delay significantly more than those who showed no such awareness. Over time, those participants rated as aware showed a steady increase in the proportion of global responses and were almost exclusively choosing the global alternative by the end of the session (see Figure 7-6). Furthermore, a significant majority of the globally aware participants were from the groups provided with the explicit delay information. This suggests that the delay information acted as a cognitive factor and increased the salience of the global contingency, presumably by making the delays more quantifiable and the changes in delay duration resulting from previous choices more apparent.

Previously, Herrnstein et al. (1993) reported that increasing a schedule's rate of change (i.e., decreasing the window size while increasing the increment size) led to an increase in the proportion of global responses made by their participants. This finding was described by Herrnstein et al. as their most robust over several experiments, but the current study failed to replicate this effect. Identifying the precise reason for this inconsistency is impossible with the immediate data because the current study was never intended as a direct replication, and there are substantial procedural differences with even Herrnstein et al.'s most comparable experiment. However, it would seem reasonable to draw some tentative conclusions. Herrnstein et al. interpreted rate of change as a straightforward cognitive factor; the greater the rate of change, the greater the proportion of global choices because increasing the rate of change made the global contingency more salient. The result of the current study would seem to cast doubt on the simplicity of this explanation. The increments used were larger than those used by Herrnstein et al. (0.4 and 1.3 s), and so presumably easier to perceive, and yet there was no effect on the proportion of global responses made. This could indicate that the delays used by Herrnstein et al. bridged a perceptual threshold, such that the participants could only detect the larger increment. If this was the case, then the absence of effect in the current study may have occurred because the increments used were all, by chance, above this threshold and so no groups had an advantage, although this explanation seems unlikely. This factor would be more important if, as Sokolowski (1996) has suggested, participants' responses are more dependent on the local increases and decreases in reward schedules between temporally adjacent trials than on the global contingency. In addition, both Herrnstein et al. and the current study treated rate of change as a single variable, but in truth it is a construct of two separate parameters: the size of the averaging window (i.e., the number of previous choices that effect the current outcomes) and the size of the increments. Conceivably, these parameters may independently affect behaviour. Given that the rate of change is important in terms of self-control, how it effects behaviour clearly warrants further research. In the current study, because the minimum and maximum values of N were constant across conditions, the averaging window and increment size were dependent parameters (see Equation 7-1). However, in a possible further study, if the minimum and / or maximum values of N were varied, then the averaging window and increment sizes could be manipulated independently.

In addition to the schedule selected, responses latencies were also recorded each trial. Over the whole session, although the rate of change had no effect, the mean response latencies were significantly affected by the provision of explicit delay information. Those participants provided with explicit delay information produced significantly shorter latencies compared to those without the delay information. After dividing the session into blocks, further analysis revealed a significant decrease in latency between the first two blocks but no differences between the subsequent blocks. This pattern of initially decreasing and then stabilising latencies was also found in Experiment 1, and it was suggested that such a pattern may indicate the early formulation of a rule-based response strategy.

Latency is often interpreted as an indication of either the degree of cognitive processing involved in a task (e.g., Clark & Chase, 1972; Eysenck & Keane, 1990) or a reflection of the shift between controlled and automatic processing (e.g., Shiffrin & Schneider, 1977). Assuming the former interpretation, in the current experiment, the greater latency of those participants without the explicit delay information could be seen as the result of an additional delay comparison process, comparing the last delay with that preceding it, before making the next choice. Those with the delay information would have found this stage unnecessary because they had been shown the relative sizes of the two delays by the digital counter. Alternatively, shorter latencies could be seen as an indicator of the participants' awareness of the global contingency. Under the design of the current experiment, the faster response latencies reduced the overall session length and thus contributed to the eventual financial reward the participant received (cf. Herrnstein et al., 1993; Kudadjie-Gyamfi & Rachlin, 1996). Therefore, any participant who truly perceived the session as a whole, as opposed to a succession of individual trials, would be expected to try to minimise response latencies as well as the average delay incurred on each trial. This study does provide some evidence for this latter explanation. Those participants who were adjudged from their questionnaire responses to be aware of the global contingencies produced significantly shorter response latencies. However, to give this effect some context, despite being statistically significant, over the entire session this equated to an average time saving of only 14 s (3p, in monetary terms).

In summary, the current study provides further evidence that maximisation and awareness of the global contingency is facilitated by the provision of additional cognitive information. However, whereas Herrnstein et al. (1993) interpreted rate of change as a straightforward cognitive factor making the global contingency more salient, the current data indicate that the effect may be more complex and deserving of further research. Above all, the data suggest that participants fail to maximise global reward under the Herrnstein procedure because they were unaware of the global contingency rather than the incentive to chose the local reward being too great. The final study of this thesis therefore tried to maximise the participants' aware of the contingencies to determine whether such awareness would lead to global maximisation.

Chapter Eight - Effects of Pre-Exposure to the Local-Global Contingencies

8.1 Rationale

The behaviour of non-humans is shaped by contact with the natural contingencies. This often means that, in operant studies using complex schedules of reinforcement, animals have to be exposed to the contingencies for long periods of time for conditioning to occur. In the context of choice or self-control research, this process is commonly facilitated by the use of a forced-choice training procedure that ensures that the subjects experience all the possible alternatives (e.g., Ainslie, 1974; Mazur & Logue, 1978). For example, Rachlin and Green (1972) used a concurrent-chain schedule to investigate commitment with pigeons (see Figure 2-3). During the initial link, by pecking response keys, the birds could choose whether to progress to a restricted terminal link that only offered a LL reward or an unrestricted terminal link that offer the traditional self-control choice of a SS or a LL reward. Each session, the pigeons experience 50 trials, the first 10 of which were forced-choice. During these forced-choice trials only one of the response keys was active so that the pigeons could only access one of the terminal links. Following the 10 forced-choice trials, 5 leading to each of the two terminal links, the pigeons were subsequently free to choose between the two alternatives.

Similar forced-choice procedures have also been used in experiments with human participants, for exactly the same reason, to ensure the participants experience all the potential outcomes (e.g., Burns & Powers, 1975; Logue et al., 1986). However, although human operant behaviour may be shaped by direct experience of the natural contingencies, the natural contingencies may also be substituted by a verbal description provided by a member of the verbal community (Lowe, 1979). Such verbal descriptions are commonly called rules. Skinner (1969) defined a rule as a *contingency-specifying stimulus*, and explained, "As a discriminative stimulus, a rule is effective as part of a set of contingencies of reinforcement. We tend to follow a rule because previous behavior in response to similar verbal stimuli has been reinforced" (p. 148). For example, the warning, "Don't touch the fire, it's hot!", describes a contingency where a touch response towards the fire will be punished by pain. As Skinner has suggested, people may be inclined to follow such rules because of a long personal history where following rules has been reinforced, and as a result, rule-following may become a generalised response (Zettle & Hayes, 1982). It has been argued that when the natural contingencies are by themselves ineffective or slow in acting, the provision of verbal instructions may be advantageous in changing behaviour (Catania, 1992). However, research has shown that, in the laboratory, verbally-governed behaviour is often subsequently more insensitive to changes in schedules of reward than behaviour that has been shaped by the contingencies (Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981).

In the first three studies of this thesis and the majority of the previous studies reviewed in chapter 3, the participants received fairly terse instructions that contained little or no information about the long-term pattern of reward. Thus, the participants were not initially made aware of the global contingency and had to learn about the experimental conditions from direct experience of the two schedules. Under such conditions, participants tended to choose the immediately larger reward despite the fact that choosing the immediately smaller reward was more beneficial in terms of global maximisation. This failure to maximise the overall reward tends to suggest that the participants were generally insensitive to the global contingency. In other words, they failed to extract accurate rules from the contingencies of reinforcement (see Skinner, 1969, for discussion). Rachlin (1995a) has implied that the rewards and time scales involved in laboratory choice procedures are simply insufficient to generate an incentive large enough to tempt a participant to choose the local reward despite "knowing" better, and therefore, any failure to maximise global reward must be the result of the participants inability to perceive the benefits of global choice. Although the previous studies of this thesis suggest that limited incentive effects can be obtained, the results from the post-session questionnaires seem to support the view that participants failed to maximise global reward because they are unaware of the global contingency.

Two studies have previously investigated the effect of providing verbal rules regarding benefits of global choice in the Herrnstein procedure. However, the findings reported have been inconsistent. Herrnstein et al. (1993) provided three groups of participants with either no hint, a strong hint, or an intermediate hint concerning the effect that current choices have on subsequent outcomes. These hints were, in effect, rules. Participants in the intermediate hint condition were told that repeatedly responding on one schedule increased the value of both on subsequent trials and repeatedly responding on the other decreased the value of both on subsequent trials. In addition to this, participants in the strong hint condition were specifically told which schedule produced which effect. The results showed that the provision of rules significantly increased the proportion of global responses, although participants still failed to maximise the global reward. However, the increase observed in the intermediate hint condition was transient. By the end of the session, the proportion of global responses made by those in the medium-hint condition had declined to a level close to that shown by those in the no hint condition. Kudadjie-Gyamfi and Rachlin (1996) attempted to replicate these effects, but using only equivalent no hint and strong hint conditions. In contrast to Herrnstein et al., they found that although the mean proportion of global responses in the strong hint condition was slightly greater, the provision of hints had no significant effect on performance.

In summary, prolonged exposure to the contingencies and forced-choice trials are often required in operant studies using non-humans to ensure that the animals learn the consequences of choice. Humans, on the other hand, have the advantage of being able to learn about complex contingencies from verbal instructions provided by others. Verbal instructions have been shown to be a powerful influence on participants' behaviour in operant experiments (see Catania, Shimoff, & Matthews, 1989), but the two studies that have so far examined the effects of verbal instructions on the Herrnstein procedure have produced conflicting results. The aim of the final study of this thesis was to try deliberately to produce participants who maximised global reward in the Herrnstein procedure by bring them into effective contact with the global contingency. The potency of two methods was assessed: verbal instructions and forced-choice.

8.2 Method

8.2.1 Design

Participants received 80 successive choice trials between two concurrently available alternatives, A and B. Both A and B responses produced a delay before the next response could be made, though the delay incurred through choosing B always remained greater than A by 5 s. The delays generally increased following an A response and decreased following a B response (see section 8.2.3). The amount of money that participants received on completion of the 80 trials was dependent on a slowly diminishing pool of money that decreased at a constant rate throughout the experimental session. Therefore, the greater the overall delay incurred, the less money the participant earned. The primary dependent variable was the proportion of B responses made throughout the experiment. In addition, response latencies were recorded on a trial by trial basis.

The experiment investigated the effect of exposing the participants to different sources of information regarding the underlying contingencies prior to the test session. A between-subjects design was used to assess the effect of verbal instructions and experience on performance. There were three conditions. In the control condition, the participants received minimal instructions. In the second condition, participants received in their instructions a detailed description of the local-global contingencies governing delay. In the third condition, the participants received a pre-experimental session where they were forced to experience the effects of repeatedly responding on each button. The experimental design is summarised in Table 8-1.

Table 8-1

Design of Experiment 4

Condition	Minimal Instructions	Description of Contingencies	Forced-choice
Group	1	2	3

Following the test, participants completed a questionnaire (see Appendix B) designed to determine their awareness of the experimental conditions.

8.2.2 Participants

Forty-eight 1st and 2nd year undergraduate psychology students (7 males and 41 females) were recruited from the departmental participant pool. Their ages ranged from 18 to 42 years, with a mean age of 21.8 years (*SD* = 5.5). Participants were randomly assigned to one of the three experimental groups and were paid as stipulated in the instructions below (see section 8.2.4).

8.2.3 Apparatus

Participants were tested individually in a small cubicle (1.5 m by 3 m) containing a desk, on which was mounted an Tiny Computers Limited Celeron 333 PC with a soundcard and a 17 inch SVGA monitor (resolution: 800 by 600 pixels). The experimental conditions were programmed as a Microsoft Windows 95 application using Borland Delphi 3, and were modified from the program used in Study Three. The main modification consisted of an increase in the number of warm-up (practice) trials that the participants had to complete, and the fact that during these warm-up trials the conditions were identical to the experimental trials (i.e., delays were governed by the same algorithm and the money pool decreased). During the 20 warm-up trials, both the group that received the minimal instructions and the group that received the description of the contingencies could choose freely between the two alternatives. However, the forced-choice group were obliged to press the same button during the first 10 trials and then the other button during the next 10 trials. This was accomplished by only displaying the compulsory button on the computer screen. Another change in the program for the present experiment was that, during the delay period, participants in *all* the conditions saw a digital clock displayed between the two buttons that counted down the number of seconds delay to the next choice point.

The program instantiated an algorithm for the delay preceding the point when the next choice could be made. On any trial, the delay incurred on each choice was dependent on the number of previous A responses in the previous 10 trials according to the following rules:

1. Each choice of A results in a delay of N s.
2. Each choice of B results in a delay of $(N + 5)$ s.
3. N is equal to twice the number of A responses in the previous 10 trials. Thus, the maximum value of N is 20 in all conditions.

Repeatedly choosing the shorter delay (A) drives up the value of N and thus the delay associated with both alternatives over a series of trials. Choosing the longer delay (B) reduces the value of N and thus in the longer-term the reward rate of *both* alternatives increases above that of the initially quicker alternative, A. The positive correlation between the number of B choices and the amount of money earned is virtually perfect ($r = .99$; $p < .01$). If A is chosen consistently over the 80 trials the overall delay incurred will be 1540 s, that results in final earnings of 238p. In comparison, if B is chosen consistently the overall delay will be 450 s, that earns 494p. Thus, the algorithm provides maximum overall utility for repeated B responses.

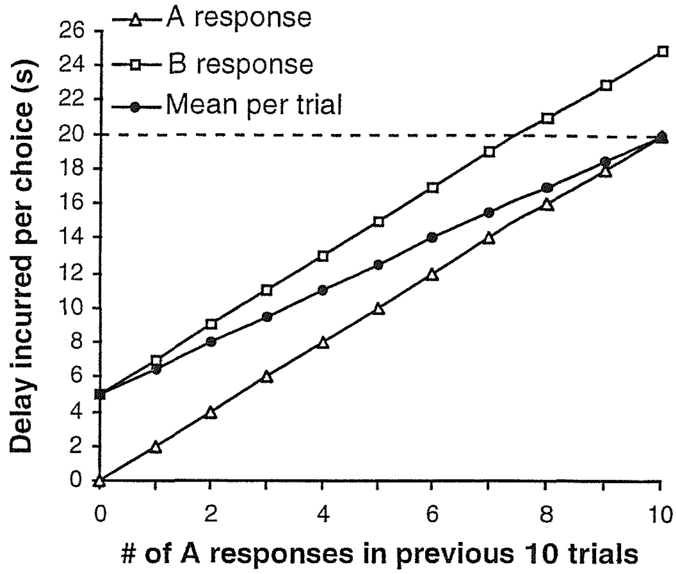

Figure 8-1. Length of delay contingent on an A or a B response as a function of the number of A responses in the 10 previous trials. The mean line indicates the average delay per trial as a function of the average number of A responses in the previous 10 trials. The dashed line at 20 on the y-axis is provided for visual clarity.

For a full description of the program, minus the changes described above, refer to section 7.2.3.

8.2.4 Procedure

All Participants were seated individually in front of a computer and asked to read the following instructions from a printed sheet. They were also provided with a printed screenshot.

Thank you for taking part in this study. Please read the following instructions carefully and ask about anything that isn't clear.

Your aim in this experiment is to earn as much money as you can. Please look at the screenshot in front of you. At the top of the screen is a pool of money. In the actual experiment this pool will start at £6.00. However, the money in the pool slowly decreases over time. You'll see a coin dropping from the pool into the bin in the centre of the screen every four seconds. Each time this happens your total earnings have declined by one penny. At the end of the experiment you will be paid whatever sum remains, so the quicker you complete the task the more money you will receive.

Your task is to make 80 choices. On each choice you must decide whether to press the left or the right button. The buttons will appear as two green squares located at the bottom of the screen and you can press them by using the mouse cursor and the left mouse button. Pressing either button will lead to a delay before you can make your next choice. During each delay both buttons will be blanked out and your money will still be declining. When the buttons reappear you can make your next choice. When you have made your 80 choices the experiment is over and you will be paid the money left in the pool.

To get you used to the task you will be given a practice session of 20 choices. This practice session does not affect the amount of money you will receive at the end of the experiment. Its purpose is to allow you to learn how the length of the delays relates to each button. Please note that sometimes in the practice session only one of the two buttons will be available for you to press. When you have completed the practice session the program will reset before you start the actual task. During the task itself, both buttons will always be available after each delay period.

Please ask if you have any questions. When you are ready, please click the mouse cursor on the start button.

Those participants provided with the description of the local-global contingencies received the following additional information together with Figure 8-2, appropriate to the left / right counterbalancing, on a separate sheet of paper.

To maximise the amount of money you will earn for completing the experiment, you need to know the rules which determine the length of delay each button will produce. Below is a diagram which shows you how the delays, given in seconds, change depending on your previous choices. Although the left button delay is always 5 seconds shorter for any individual choice, repeatedly choosing it generally <u>increases</u> the delay produced by both buttons on subsequent choices. Conversely, although the right button delay is always 5 seconds longer for any individual choice, choosing it generally <u>decreases</u> the delay produced by both buttons on subsequent choices. Therefore, to minimise the average delay per choice, and hence maximise the amount of money you will receive, it is better to press the right button throughout the task.

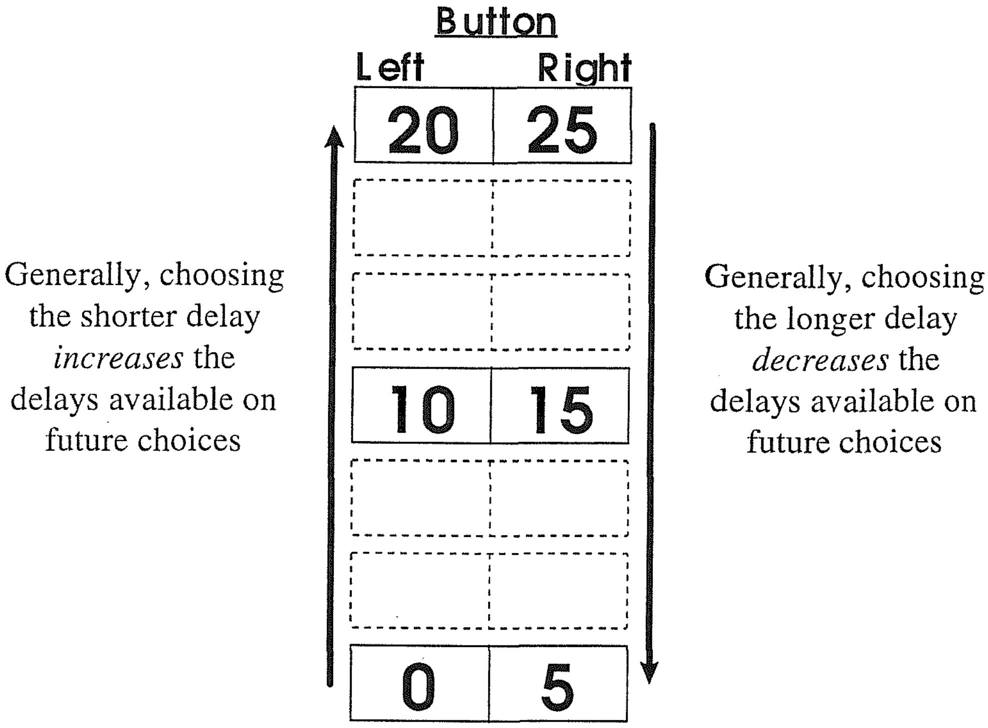

Figure 8-2. Diagram given to participants in the description of contingencies condition. This version was given to those participants who made A responses on the left button.

A trial began when the green buttons appeared at the bottom of the screen. The participant made a choice by clicking the mouse cursor on either the left or right button on the screen. The chosen button became black with a green outline while the other button disappeared. After the incurred delay, the next trial began and both buttons reappeared. Response times for both A and B choices were measured from the time the buttons appeared on the screen to the time when a button was pressed. To avoid a possible left / right bias, the function of the response keys was counterbalanced (i.e., half the participants in each group made an A choice on the left button and half made an A choice on the right button).

At the start of the practice and experimental phase of the study the money pool was set at £6.00, and the register of previous choices that determined the value of N was pre-set with the sequence 'ABABABABAB' so that the initial value of N was 10. During both phases, the warm-up/forced-choice and the experimental, the buttons produced an inter-choice delay that varied according to the algorithm described in the section 8.2.3. Initially, all participants were given 20 warm-up trials to familiarise themselves with the screen display, controls, and the schedules. However, participants in the forced-choice condition had access to only one button on each trial, the other remained black. These participants were forced to experience 10 choices on one button and then 10 choices on the other button, counterbalanced between subjects (i.e., half were forced to choose the left first and half the right first). Following the warm-up trials, all participants received 80 experimental trials. On completion of the choice procedure, participants were instructed to fill out a questionnaire designed to assess their awareness of the algorithm underlying the pattern of point delivery. The scoring system for this questionnaire is described in chapter 6, section 6.2.4.

8.3 Results

The effect of the independent variables on the mean proportion of B responses made during the 20 warm-up trials and the 80 experimental trials is shown in Figure 8-3. An independent samples *t* test was used to determine whether, during the 20 trials of the warm-up session, there was a difference in the proportion of B choices made by the minimal instructions group and the group provided with the description of the contingencies. The forced-choice group were excluded from this analysis because they had to select B 50% of the time. The result showed that those with the description of the contingencies chose B significantly more during the practice session than those with only minimal instructions, $t(30) = 4.01, p < .05$.

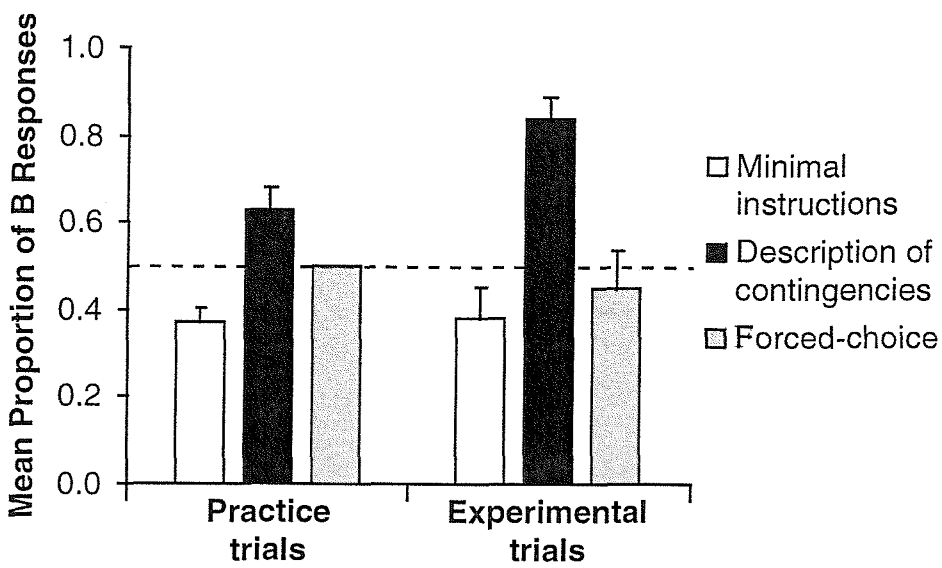

Figure 8-3. Mean proportion of global (B) responses by condition, shown for the 20 warm-up trials and the 80 experimental trials. One standard error is shown above each mean. Note that during the warm-up trials those in the forced-choice condition had to select B 50% of the time. The dashed horizontal line at 0.5 on the y-axis signifies choice indifference.

For the experimental trials, to examine the effect of the different types of pre-exposure to the global contingency, either via written descriptions of the contingencies or forced-choice, a series of one-sample *t* tests were used to determine if the mean proportions differed from the choice indifference value of .5. The results of these tests showed that the means of the minimal instructions group and the forced-choice group were not statistically different from .5, but that the group provided with the description of the contingencies was significantly greater, $t(15) = 6.70, p < .05$. To examine the effects on the overall pattern of choice and the time course of those effects, the 80 experimental choices were divided into four blocks of 20 trials (Blocks 1-4). The mean proportion of B responses per block was calculated and a mixed-design ANOVA (Condition x Block) was used to determine main effects and any interaction between the variables. Because the initial analysis, excluding block, violated the assumption of homogeneity of variance, Box's (1954) correction was applied to modify the degrees of freedom and make the test more conservative. However, even with this correction the test showed that there was a significant main effect of condition, $F(1, 15) = 11.47, p < .05$. Subsequent post-hoc analysis using the Games-Howell test, which does not assume homogenous variance, showed that providing a description of the contingencies increased the proportion of B responses made over the 80 trials as compared to both the minimal instructions and forced-choice groups.

The mixed design ANOVA was also used to determine if there was main effect of block and any interactions between block and the three conditions. The mean proportion of B responses per block for each of the conditions is shown in Figure 8-4. As the data violated the assumption of homogeneity of covariance the Greenhouse-Geisser correction was used to modify the degrees of freedom to make the test more conservative (see Howell, 1997). The results showed no significant effect of block, indicating no change in the proportion of B choices as the experiment progressed, $F(1, 45) = 3.01, p > .05$. There was also no interaction between block and condition, $F(2, 45) = 0.91, p > .05$.

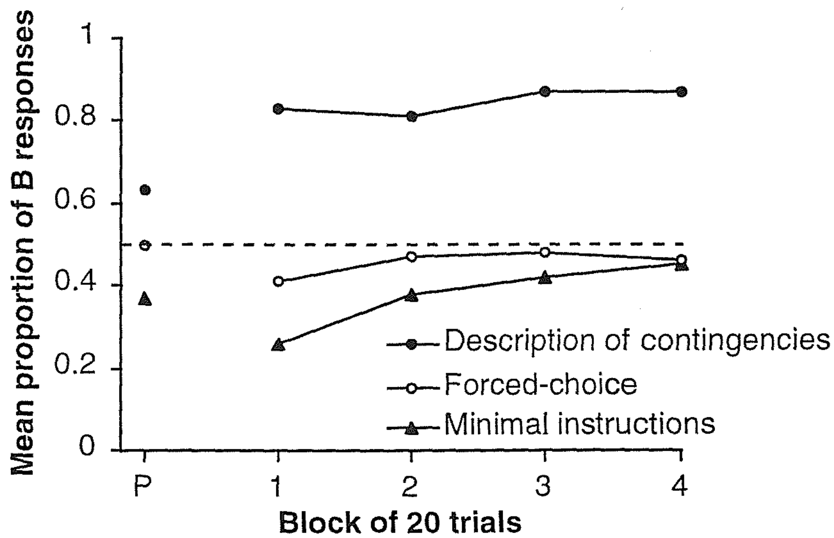

Figure 8-4. Mean proportion of global (B) responses made in each condition shown in blocks of 20 trials. P represents the 20 warm-up (practice) trials. Note that during the practice trials those in the Forced-choice condition had to select B 50% of the time. The dashed horizontal line at 0.5 on the y-axis signifies choice indifference.

The postexperimental questionnaire asked the participants which button they would select if their choice was restricted and they had to consistently press the same button throughout the session, and to provide justification for their answer. 29 (60%) of the participants reported that they would chose button B, which would result in maximising global reward if chosen consistently, while 18 (38%) expressed a preference for button A. The remaining participant expressed no preference between the two buttons. The distribution of participants' preferences, either global or local, is shown in Table 8-2. A chi-squared test were performed to determine if there was a relationship between the experimental conditions and choice preference. The result showed that the choice preferences of the participants given explicit information was significantly different from those participants who receive no information , $\chi^2(1, N = 31) = 7.63, p < .05$.

Table 8-2

Participants' Choice Preference per Condition

		Choice Preference	
Condition	*n*	A: Local	B: Global
Minimal instructions	15[a]	9	6
Description of Contingencies	16	2	14
Forced-choice	16	7	9

[a] One participant expressed no preference between the two alternatives.

Of the 29 participants who expressed a preference for the global button, 8 (2 from the minimal instructions condition, and 3 from each the description of contingencies and forced-choice conditions) reported that they believed the optimal strategy to involved at least occasionally choosing the alternative button. In comparison, of the 18 participants who said they would press the local button repeatedly, 7 failed to report any awareness of the overall rules. However, the remaining 11 participants all mentioned the benefit of occasionally pressing the global button when describing the strategy that would earn the most money.

Figure 8-5 shows the proportion of B responses per block depending on the preferred schedule expressed by the participant in the questionnaire. The combination of unequal sample size and heterogeneity of covariance made these data unsuitable for analysis using ANOVA. However, a Mann-Whitney U test, that compares ranks instead of means (provided simply to illustrate the difference) and so is not dependent on these assumptions, showed that the 29 globally aware participants made significantly more B responses over the complete 80 trials ($M = .80$, $SD = .18$) than those participants who preferred the local alternative ($M = .18$, $SD = .19$), $U = 15.00$, $p < .05$.

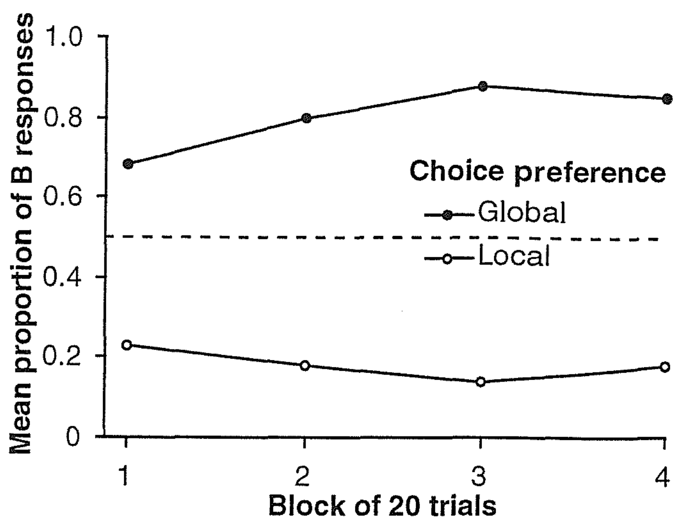

Figure 8-5. Mean proportion of global (B) responses per block of 20 trials shown for participants reported in the questionnaire that they would choose the global button if restricted to pressing only one (n = 29), and those who would choose the local button (n = 18). The dashed line at 0.5 on the y-axis signifies choice indifference.

The response latencies were collated for each participant. Again, the 80 choices were divided into 4 blocks of 20 trials (Blocks 1-4) and the mean response latency per block for each condition calculated. A mixed-design ANOVA (Condition × Block) was used to determine any main effects of the condition and any interactions between the condition and block. The initial analysis revealed that the condition had no significant effect on the overall response latency, $F(2, 45) < 0.01$, $p = 1.0$. However, incorporating the Greenhouse-Geisser correction, the analysis showed a significant main effect of block, $F(1, 45) = 13.30$, $p < .05$, but no interaction between condition and block, $F(2, 45) = 0.64$, $p = .53$. The mean response latencies for each block are shown in Figure 8-6. Analysis of the main effect of block using paired t tests showed a significant decrease in response latencies between Block 1 and Block 4, $t(47) = -2.10$, $p < .05$, but not between the any of the intervening blocks.

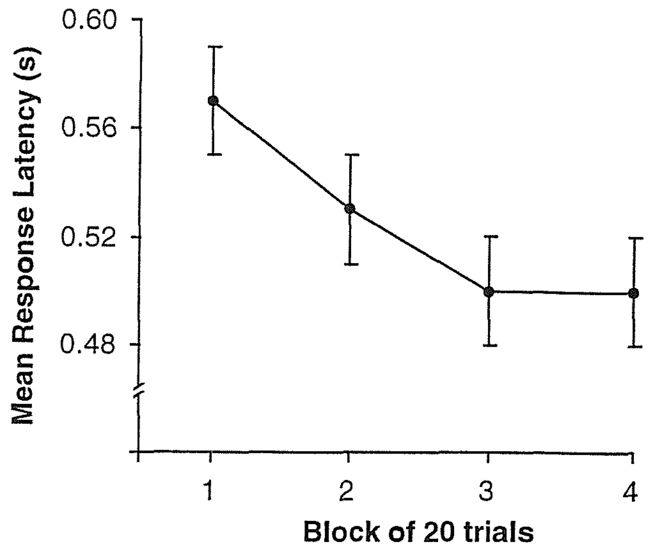

Figure 8-6. Mean response latencies by block of 20 trials. One standard error is shown above and below each point.

Because awareness of the global contingency was found to be associated with improved performance, the relationship between awareness and latencies was also examined. The mean response latencies of those participants rated as globally aware (n = 29, M = 0.52 s, SD = 0.11) and those rated as unaware (n = 18, M = 0.51 s, SD = 0.11) were calculated, but not found to be significantly different. In addition, a series of Pearson correlations were conducted to determine whether there was a relationship between latency and proportion of B choices made during each block. None of these correlations were significant, r = -.03, -.16, -.01, -.03, for Blocks 1 to 4 respectively, p > .05.

The raw data from this experiment are presented in Appendix C.

8.4 Discussion

The results of this study showed clearly that providing the participants with a written description of the local-global contingencies and details of the optimal choice strategy significantly increased the proportion of global responses in comparison with the performance of those participants who only received minimal instructions and those who experienced the forced-choice procedure. Although the forced-choice procedure produced slightly more global responses than the minimal instructions condition, the analysis revealed this difference was not statistically significant. Moreover, whereas the overall proportion of global responses made by the forced-choice and the minimal instruction group were not significantly different from those expected from chance responding (50-50), those participants who received the description of the contingencies showed a significant preference for the global outcome over the local alternative. However, even with the advantage of contingency descriptions, only one participant selected the global button exclusively. This improvement in performance found with the provision of a description of the contingencies in the current study compares favourably with the findings previously reported by Herrnstein et al. (1993) and contrasts with Kudadjie-Gyamfi and Rachlin's (1996) failure to find an effect. Kudadjie-Gyamfi and Rachlin interpreted their result as evidence for "...the ultimate lack of power of this sort of hint ..." (p. 66). However, given the positive findings of both the present experiment and that of Herrnstein et al., it would seem reasonable to question whether the terms and phrases that Kudadjie-Gyamfi and Rachlin used to construct their description of the contingencies was readily understand by the participants.

The reason for the lack of improvement in global performance following the forced-choice procedure is unclear. At the end of the experiment, after the experimenter had explained the study's purpose, several of the participants informed the experimenter that they had not perceived a link between the warm-up and the experimental sessions. However, there is no evidence to suggest that this was anything more that a post-hoc rationalisation. It would seem more likely that, for whatever reason, when choice was restricted the participants did not attend to the outcomes of their responses, and so the forced-choice procedure would not have promoted global awareness. If this was the case, then it could be determined by assessing the participants' awareness of the contingencies immediately after the force-choice procedure.

The purpose of the description of the contingencies and the forced-choice procedure was to facilitate the participants' awareness of the global contingency. Analysis of the questionnaires revealed that, over all three conditions, 60% were rated as globally aware because they reported that they would choose the global schedule if they had to exclusively respond on one schedule for the entire session. As expected, this globally aware group included nearly all the participants who were provided with the description of the contingencies. Compared to those participants who expressed a preference for the local schedule, those rated as globally aware made a significantly higher proportion of global responses during the experimental session. Nevertheless, the majority of this group failed to maximise global reward, and though obviously aware of the benefits for global choice, several members of this group reported that they believed the optimal strategy to involve at least occasionally choosing the local reward. Interestingly, this included three participants who were provided with the description of the contingencies that unequivocally, or so it was originally believed, stated the optimal strategy.

In Experiments 1 and 3 it was suggested that the decline in response latencies over the session exhibited under all conditions may indicate the early formulation of verbal rules. No corresponding decline in response latencies were revealed in this experiment but the design of this study differed by the addition of a block of warm-up trials. Unfortunately, latencies were not recorded for this period. If they had been it is possible that a similar decline in latencies would have been found, given the fact that in the previous studies, latencies decreased most between the first two blocks. In the absence of latency data, the fact that participants did report rules at the end of the experiment suggests that the participants did, at some point in the procedure, generate their own (flawed) rules. Also, the fact that some of the participants who received the description of the contingencies recounted suboptimal rules indicates that, in the laboratory setting at least, self-instruction is more potent than instructions provided by an experimenter.

In conclusion, the present study clearly showed that providing verbal descriptions of the contingencies promotes global awareness and also results in participants making a greater proportion of global responses. However, the study failed in its aim to produce participants who maximised global reward because even with the advantage of the verbal descriptions the majority of the participants still occasionally chose the local reward. If participants cannot be induced to maximise global reward when the experimenter explicitly describes the optimal response strategy to them, it must be questioned whether any manipulation can be effective enough to do so.

Chapter Nine - General Discussion

9.1 Introduction

Since the establishment of the SS versus LL model of self-control (see chapter 1), researchers have successfully identified many of the factors that influence behaviour under such conditions (see chapter 2). Nevertheless, despite the knowledge accumulated over a quarter of a century of experimentation and discussion, researchers and practitioners are still unable fully to predict and control those behaviours commonly seen to involve self-control and impulsiveness.

Rachlin's (1995a) assertion that the traditional SS versus LL model does not characterise many of the situations to which the everyday use of the term self-control is usually applied has led to the development of an alternative model that seems to fit better (see chapter 3). Within this alternative model, self-control is seen as choosing to act in ways that delivers relatively small, local (immediate) rewards but that contribute to a larger, global (overall) pattern of reward; impulsiveness is choosing to act in ways that deliver relatively large, local rewards but at the expense of the global pattern of reward. These conditions have been simulated in the laboratory using the human choice procedure reported by Herrnstein et al. (1993), in which local and global rewards are directly opposed. However, compared to the traditional model, relatively few studies using Rachlin's (1995a) newer paradigm have been conducted.

The general aim of this thesis was to assess the validity of Rachlin's (1995a) new structural analysis of the circumstances in which people commonly talk about self-control and impulsiveness. This thesis comprises a series of four experiments (see chapters 5 - 8) designed to investigate factors that may affect self-control in the local versus global choice procedure developed by Herrnstein et al. (1993). In addition to this primary aim, this thesis also became an assessment of the practicalities of using this choice procedure with human participants, with specific reference to the types of rewards used (i.e., points or delays) and the manipulanda that the participants had to operate to receive them (i.e., buttons or touchscreen or computer mouse).

9.2 Review of Experimental Studies

The most striking finding of all four experiments, the salient features of which are summarised in the upper section of Table 9-1, was the participants' relative lack of sensitivity to the global contingency. There was a strong tendency to choose the larger of the two immediately available local rewards, despite the fact that choosing the smaller local reward would have been more beneficial in terms of maximising global reward. Similar results were produced by the earlier research, discussed in chapter 4. However, Experiments 1, 3, and 4 showed that this tendency could be moderated by the provision of certain types of information, including prospective information, social comparative information and explicit delay information. Information regarding the global contingencies resulted in participants choosing a greater proportion of the smaller immediate rewards thus increasing global maximisation. Analysis of the post-test questionnaires of all four studies suggested a strong correlation between participants' task performance and their ability to make verbal reports relating to the global contingency. These findings would seem to suggest that participants failed to maximise global reward because they were unaware of the global contingency rather than because the incentive to chose the larger local reward was too great.

Table 9-1

Summary of experiments: reward dimension and factors

Experiment	Reward dimension	Factors
1	Points	Prospective information
		Social Comparison
		Magnitude of differential
2	Delay	Magnitude of differential
3	Delay	Rate of change
		Explicit delay information
4	Delay	Pre-exposure to contingencies
Pepperell, Remington, & Warry (2000)		
1	Delay	Rate of change
		Explicit delay information
2	Delay	Previous choice information
		Performance information

Note. Experiments by Pepperell et al. (2000) are described in sections 9.2.2 and 9.2.4.

The effect of the experimental manipulations on global maximisation and on the participants' awareness of the global contingencies together with response latencies will be discussed separately.

9.2.1 Global Maximisation

In Experiment 1, three factors, previously identified under the traditional model as important in self-control, were translated into forms compatible with a computer-based instantiation of the Herrnstein procedure. In this experiment the participants had to chose repeatedly between two different amounts of points. The results showed that providing prospective information regarding the value of the local alternatives on the current trial, and social comparative information (by displaying the participant's score alongside that of an expert) both increased the proportion of global responses made. When the differential between the two local rewards was large, the proportion of global responses was reduced. However, the effect of the differential size was negated by the provision of prospective information. This finding seemed to suggest that points were not a sufficiently powerful enough incentive to overcome the effects of a purely cognitive manipulation.

Because the results of Experiment 1 suggested that points had relatively low incentive value in the local-global paradigm, the methodology for Experiment 2 was modified. In this and subsequent studies the reward dimension under the participants' control was the length of the inter-trial delay. In Experiment 2, the differential value was varied between-subjects across three levels (3, 5, and 7 s), but the data did not reveal any coherent effect of this manipulation. It was suggested that the differential variable had both perceptual and incentive qualities. As the differential increases, Weber's law (see Sekuler & Blake, 1994) predicts that it will become more difficult to detect changes in delay because the change becomes a relatively smaller proportion of total delay. However, as the differential increases the immediate penalty incurred from choosing the global option (i.e., longer delay on that trial) also increases. Unfortunately, these two aspects could not be easily disentangled by using this experimental design.

It is possible that participants may fail to maximise global reward in the Herrnstein procedure because they are insensitive to the gradual changes in current reward sizes caused by their previous choices. Experiment 3 examined the effect of varying the rate at which both the concurrently available rewards changed between trials. This is jointly determined by the increment size and the size of the averaging window. In addition, because Experiment 2 raised the possibility that the participants' ability to perceive changes in delay was a potential confound, the importance of this factor was assessed by providing half the subjects with explicit delay information in the form of a digital countdown timer that showed the length and progression of each period of delay. The results showed that the rate of change of reward size used in this study (2, 4, and 6 s) did not affect the participants' allocation of choices. However, the provision of explicit delay information did significantly increase the proportion of global responses made as the session progressed. This finding adds further weight to the conclusion that participants fail to maximise the global reward when they are unable to verbalise the global contingency. Though, it is important to emphasise that although there is a strong correlation between verbalisation and global maximisation there is no evidence to suggest that the relationship is causal because the assessment of awareness was only made post-hoc.

Experiment 4 focused more closely on the awareness hypothesis. Two methods for bringing the participants into contact with the global contingency were assessed. One group of participants received instructions that included explicit details of the experimental contingencies and identified the optimal choice strategy while another group underwent a forced-choice training procedure that ensured the participants experienced the consequences of repeatedly pressing each button. A third group, acted as the control, receiving only basic instructions. The provision of the explicit instructions resulted in a greater proportion of global responses than the other two conditions which were not statistically different from each other. Nevertheless, in spite of the explicit instructions, only one participant chose the global option exclusively; the majority still occasionally chose the immediately larger local reward.

9.2.2 Global Maximisation: Continuing Research

Following the completion of the studies reported in this thesis, two further experiments were conducted in the Southampton laboratory. These experiments (Pepperell, Remington, & Warry, 2000) have some bearing on the interpretation of the existing findings and are reported briefly below. Any relevant findings from these two studies will be incorporated into the general discussion.

The first of these additional two studies was a direct extension of Experiment 3. In Experiment 3, it had originally been hypothesised that the greater the rate of change the easier it would be for the participant to perceive the global contingency. However, the results showed that the size of the increments used had no effect on the responses made. It is possible that no effect was found because the increments used were relatively similar in size (2, 4, and 6 s). However, they did not cover the full range of potential increments that could be accommodated within the range of the *N* parameter (0 to 24 s). The experiment carried out by Pepperell et al. (2000) was identical to Experiment 3 (see chapter 7), except that different increment sizes were used and a different experimenter ran the sessions. The experiment used a 3 x 2 nested factorial design to investigate the effects of two independent variables on the proportion of B responses. The first independent variable was the rate at which the delay changed as a result of the previous choices. The three levels of rate of change were increments of either 6 s with an averaging window of 4 trials (which replicated a condition in Experiment 3), 12 s with an averaging window of 2 trials, or 24 s with an averaging window of 1 trial. The second independent variable was the presence or absence of explicit delay information. The participants were 60 undergraduate psychology students (51 female and 9 male) recruited from the departmental participation pool.

The effect of the independent variables on the mean proportion of B responses is shown in Figure 9-1, which, for comparison also includes the results from Experiment 3. On visual inspection, the general trends in the data seemed to fit well with the findings of Experiment 3, except for the mean proportion of B responses made by the group with increment size of 6 s and with delay information present. This group replicated the conditions of one of the groups in Experiment 3, so, despite the large inter-subject variability, the difference in means is difficult to explain. However, because the data from this isolated group were highly inconsistent with the overall trends, it was decided to exclude Pepperell et al.'s (2000) increment 6 conditions from the statistical analysis.

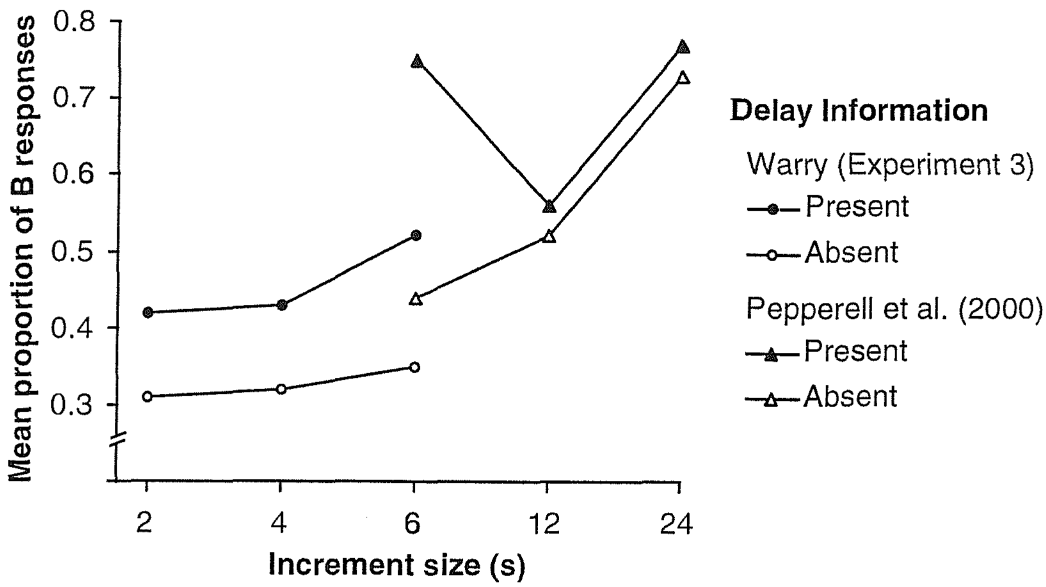

Figure 9-1. Mean proportion of global (B) responses made by level of increment size. The data points marked with circles are from Experiment 3 of this thesis. The data points marked with triangles are from Pepperell, Remington, and Warry (2000), Experiment 1.

Pepperell et al. (2000) examined the effect of the independent variables on the overall pattern of choice and the time course of those effects. The sessions were divided into four blocks of 20 trials (Blocks 1 - 4) and the mean proportion of B responses per block calculated. A mixed-design ANOVA (Rate of change × Delay information × Block), was used to determine main effects and any interactions between the factors. The initial analysis, excluding block, revealed only a significant main effect of increment size, $F(1, 36) = 8.28$, $p < .05$. The provision of explicit delay information had no effect on the proportions of responses, $F(1, 36) = 0.33$, $p = .57$. Participants choosing with an increment of 24 s over an averaging window of 1 trial made significantly more B responses than those participants choosing with an increment of 12 s over an averaging window of 2 trials. Unusually, with block included in the analysis the data did not violate the assumption of homogeneity of covariance and so no corrective procedures needed to be employed. The analysis revealed a main effect of block, indicating an increase in B responses as the session progressed, $F(3, 108) = 23.68$, $p < .05$, but no interaction between block and rate of change, although this was approaching significance, $F(3, 108) = 2.43$, $p = .07$. The main effect of the rate of change and the time course effect are shown in Figure 9-2.

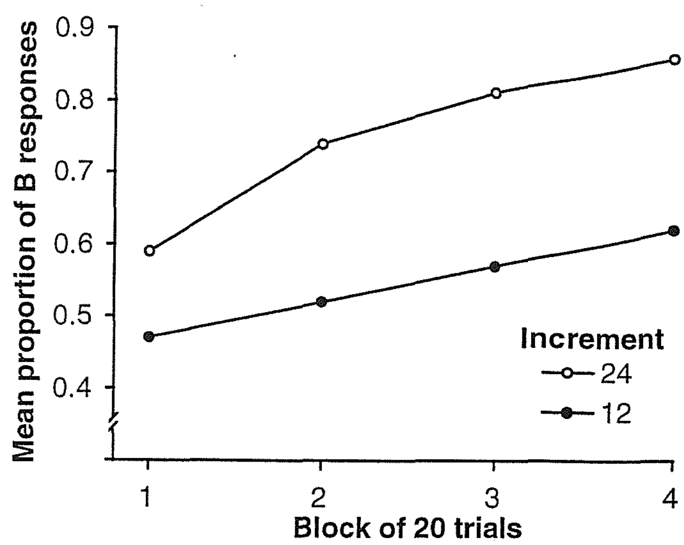

Figure 9-2. From Pepperell, Remington, and Warry (2000), Experiment 1. Mean proportion of global (B) responses per block of 20 trials shown for increment sizes 12 and 24.

Interestingly, these results contrast with Experiment 3, which found no main effect of the rate manipulation, but found that the provision of delay information did produce a greater proportion of B responses in the latter half of the session. Together, these results suggest that below a certain value the rate of change makes no difference to the perception of the global contingency, but at these values the provision of delay information does promote global responses. When the rate of change crosses the threshold, the global contingency presumably becomes salient and the provision of delay information becomes irrelevant. Although not strictly statistically legitimate, the mean proportion of B responses for Experiment 3 and Pepperell et al. (2000) were combined to try and confirm these hypotheses (see Figure 9-1, excluding the increment size 6 groups of Pepperell et al.). An ANOVA (Rate of change × Delay information) showed a mean effect of rate of change, $F(4, 90) = 8.53$, $p < .05$, but no main effect of delay information, although this was approaching significance, $F(1, 90) = 3.59$, $p = .06$. From the two separate analyses of Experiment 3 and Pepperell et al., it appeared likely that there was an interaction between rate of change and delay information, in that delay information lost its effect as rate of change increased. Nevertheless, the combined analysis revealed no such interaction between the two factors, $F(4, 90) = 0.25$, $p = .91$. However, the interpretation of this analysis is tentative given the fact that the results are not from a single experiment.

Moreover, it is unclear whether these findings can be generalised or whether they are, because of the way that people perceive and quantify the passage of time, unique to the use of delay as the reward dimension. However, it should be noted the Weber's law (see Sekuler & Blake, 1994) applies to the ability to detect change in any physical quantity (e.g., brightness, length, pitch, etc.) and not just time. It is also important to reiterate that the rate of change is a compound variable. If the minimum and maximum values of the two local rewards are constant, then as the increment size increases the number of previous choices that affects the current outcomes must decrease. Whether the effect of increment size and window size can be differentiated has yet to be tested experimentally.

The second experiment conducted by Pepperell et al. (2000) assessed the impact of methods that provide additional information, helping participants to perceive the wider context of their choices. Previous studies have shown that providing information regarding performance relative to others (e.g., the social comparative information used in Experiment 1 of this thesis) and physically arranging choices to emphasise the long-term consequences of current choices (Kudadjie-Gyamfi & Rachlin, 1996) increased the mean proportion of global responses made by participants.

Pepperell et al. (2000) used an experimental procedure identical to one of the conditions used in Experiment 3 (increment size was 4 s and an averaging window of 6 trials), except for the following changes. Each session consisted of 96 trials, and the rate at which the money pool diminished was reduced to 1 p every 5 s so that the maximum and minimum payouts were similar to Experiment 3. The experiment used a 2 × 2 nested factorial design to investigate the effects providing two different types of information on the proportion of global responses made. The information was provided every 12 trials and was display for 20 s before the choice procedure restarted. The first type was previous choice information. That consisted of a display, in terms of "left" and "right", of the participant's last 6 choices (the averaging window). The second type was performance information, that consisted of a red, horizontal bar that moved left or right depending on the percentage of global responses made by that point in the session. Each time this information was displayed it was calculated by dividing the total number of B responses made by the total number of trials completed. The left end of the bar represented 0% and was marked "poor"; the right end of the bar represented 100% and was marked "good". The two levels of both variables were determined by whether the information was, or was not, available to the participant. An example screenshot showing the display of both types of information is shown in Figure 9-3.

In the condition where neither type of information was available, the participant experienced a blank screen for 20 s before the choice procedure restarted. The participants were 64 (33 female and 31 male) students, both undergraduates and postgraduates, recruited from the departmental participant pool and from email adverts and posters displayed around the University of Southampton.

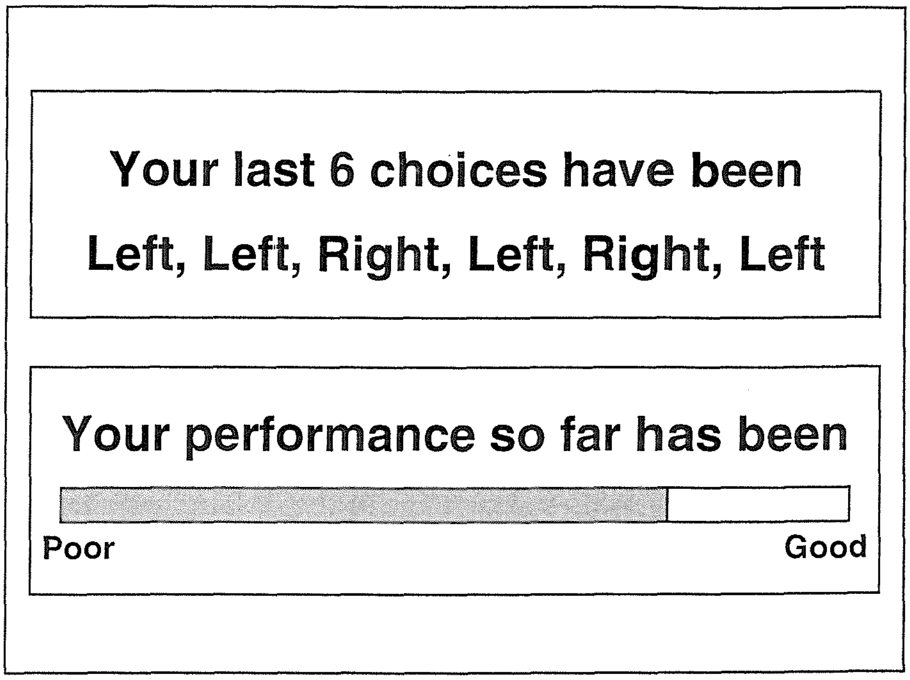

Figure 9-3. From Pepperell, Remington, and Warry (2000), Experiment 2. Example screenshot displaying previous choice information (above), that listed the participant's previous 6 choices, and performance information (below), that showed the proportion of global choices made by that point in the session

The effect of the two independent variables on the mean proportion of B responses are shown in Figure 9-4. To examine the effect of the independent variables on the overall pattern of choice, and the time course of those effects, the 96 choices were divided into four blocks of 24 trials (Blocks 1 - 4). The mean proportion of B responses per block was calculated and a mixed-design ANOVA (Previous choice information × Performance information × Block), was used to determine main effects and any interactions between the factors. The initial analysis, excluding Block, revealed a significant main effect of performance information, $F(1, 60) = 12.46$, $p < .05$. Those participants provided with performance information made a greater proportion of B responses than those who did not have this information. The provision of previous choice information did not affect the responses made, $F(1, 60) = 1.02, p = .32$, and there was no interaction between the two factors, $F(1, 60) = 0.03, p = .87$.

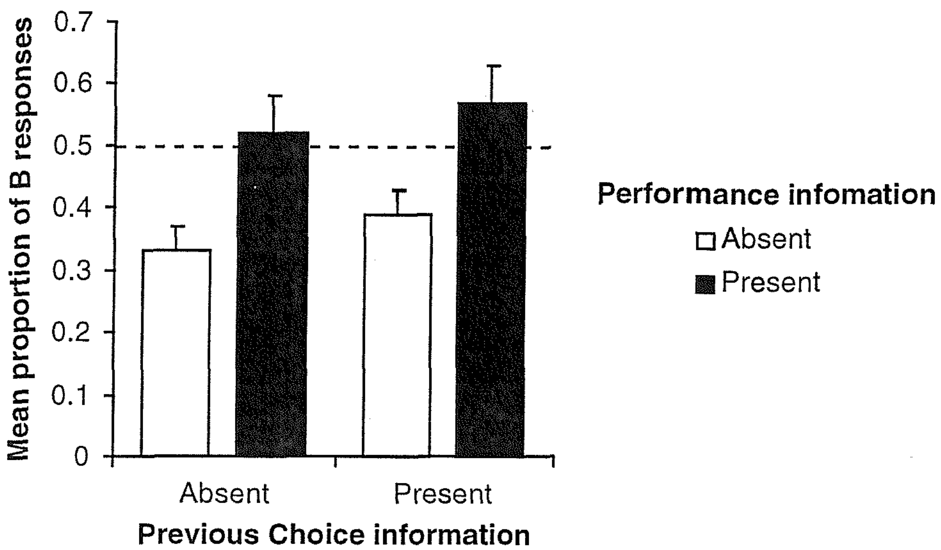

Figure 9-4. From Pepperell, Remington, and Warry (2000), Experiment 2. Mean proportion of global (B) responses by type of information provided. The dashed horizontal line at 0.5 signifies choice indifference.

The analysis including block violated the assumption of homogeneity of covariance and so the Greenhouse-Geisser correction was used to modify the degrees of freedom. The analysis revealed a main effect of block indicating an increase in the proportion of B responses as the session progressed, $F(2, 141) = 5.55, p < .05$. No interaction was found between block and previous choice information, but there was an interaction between block and performance information, $F(2, 141) = 3.12, p < .05$. The main effect of performance information and the interaction between block and performance information are shown in Figure 9-5. Further analysis with paired t tests showed that with performance information available there was no significant difference between Blocks 1 and 2, but there was a significantly higher proportion of B responses between Block 1 and 3 and Block 1 and 4, respectively $t(31) = 2.84$ and $3.55, p < .05$.

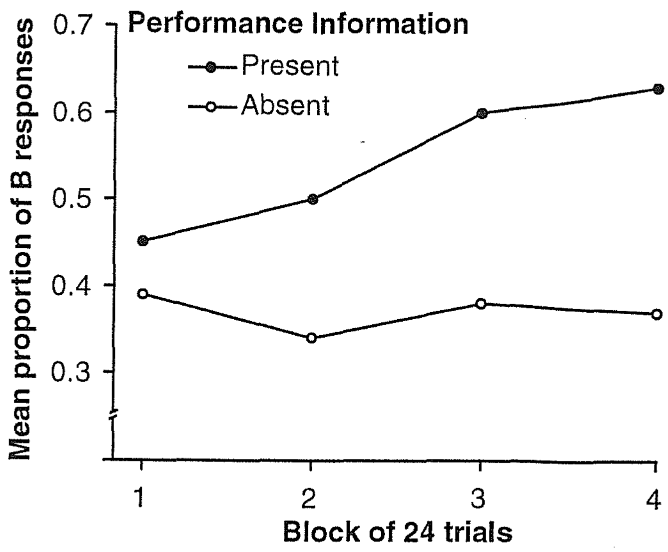

Figure 9-5. From Pepperell, Remington, and Warry (2000), Experiment 2. Mean proportion of global (B) responses per block of 24 trials shown for conditions with performance information available and unavailable.

The results provided by this second study again showed that cognitive information can modify the way humans allocate their choices under conditions of local versus global choice. Similar to the social comparative information used in Experiment 1, the performance information (good versus poor) allowed participants to determine the efficiency of their current behaviour and adjust their response strategy accordingly (i.e., maintain a good strategy and change a poor one). Also, the finding that there was no significant increase in the proportion of global responses made in Block 1 until Block 3 indicates that participants needed to experience the information on several occasions before it had an impact of their choices. In Experiment 1, the possibility existed that the social comparative information may have promoted global choice simply because it provided the participants with additional time to process the information on the relationship between responding and reward. The same criticism cannot be applied to the performance information used in this study because all participants experienced (information) breaks from the task of identical duration.

The way in which the previous choice information was provided seems formally similar to the trial grouping manipulation previously used by Kudadjie-Gyamfi and Rachlin (1996), in that the participants made a series of choices interspersed with enforced breaks. However, whereas the manipulation used by Kudadjie-Gyamfi and Rachlin was productive, the provision of previous choice information in this study was ineffective at promoting global choice. Although speculative, it could be that the size of the trial grouping is an important variable. In Kudadjie-Gyamfi and Rachlin, the trials were grouped together in sets of three, and in the current study they were grouped together in sets of twelve.

9.2.3 Global Awareness and Response Latency

In addition to recording and analysing each study in terms of the pattern of responses made by the participants, the experiments reported in this thesis also included a more rigorous assay of the participants' awareness of the global contingencies than had been attempted in previous research using the similar procedures (see chapter 3). Given Herrnstein et al.'s (1993) assertion that awareness is a prerequisite for global maximisation, it is surprising that this aspect has been neglected by previous research. However, to show that awareness is a prerequisite of global maximisation, and not just a correlate, it would be necessary to definitively show that awareness precedes any improvement in performance.

All four experiments revealed a correlation between the participants' rating of global awareness and the proportion of global responses that they made; those participants rated as aware of the local-global contingencies made a significantly greater proportion of global responses during the session. Nevertheless, in Experiments 1, 2, and 3, the majority of the participants in each study were rated as being unaware of the global contingency. In these three experiments, the independent variables that constituted parameters of the reward algorithm (i.e., differential in Experiments 1 and 2; rate of change in Experiment 3) did not affect the participants' relative awareness of the contingencies. A greater proportion of those participants provided with explicit delay information in Experiment 3 where rated as being globally aware. The results of Experiment 4 differed in that a majority (60%) of the participants were rated as globally aware. This was expected because a third of the participants in this experiment were provided with a written description of the contingencies prior to testing. Nevertheless, despite this information, 2 members of this group (13%) were still rated as unaware of the global contingency at the end of the session, expressing a preference for the larger local reward in the questionnaire.

Response latencies were also recorded, on a trial by trial basis, in the expectation that such data would shed further light on factors determining the participants' responses. For example, if participants were using the additional information provided in certain conditions it would seem likely that their latencies would be longer. In all the experiments, the general trend was for a decrease in response latencies over approximately the first half of the experimental session followed by stabilisation. Latencies were unaffected by changes in the differential value, examined in Experiments 1 and 2, and by the rate of change, examined in Experiment 3. In Experiment 1, the provision of additional prospective information at the start of the choice period (see Logue, 1988) led to an initial increase in latency at the beginning of the session. Conversely, latencies were consistently shorter when explicit delay information was provided in Experiment 3.

Unfortunately, it is unclear whether awareness of the local-global contingencies preceded improvement in task performance or followed it, because the assessment of awareness was only made post-hoc. It is possible that the pattern of declining and then stabilising response latencies may indicate the early formulation of a rule-based response strategy, even though the rules constructed may not necessarily reflect the optimal response strategy. Alternatively, the pattern of response latencies could equally well reflect an implicitly learned minimisation of task delay which precedes awareness.

9.2.4 Awareness and Latency: Continuing Research

Data regarding the participants' global awareness and response latencies were also collected in the two further studies of Pepperell et al. (2000). In the first experiment, which manipulated the rate of change and the provision of explicit delay information, 24 of the 40 participants (60%) expressed a preference for the global choice, and 21 of these reported rules that approximated the local-global contingencies. A t test showed that the 21 globally aware participants made a significantly higher proportion of global (B) responses ($M = .79$, $SD = .15$) than the 19 unaware participants ($M = .48$, $SD = .22$), $t(38) = 5.07, p < .05$. A chi-squared test showed that there was a relationship between global awareness and experimental condition, $\chi^2(1, N = 40) = 12.13, p < .05$. Of the 21 globally aware participants, 16 (76%) were in the condition with an increment of 24 s (averaging window, 1 trial) and 5 (24%) were in the condition with increments of 12 s (averaging window, 2 trials). Together with the Experiment 3, the evidence would seem to suggest that the rate of change needed to be rapid (large increment and small averaging window) for it to promote awareness of the global contingency.

Response latencies were collated for each participant, and means calculated for blocks of 20 trials. A mixed-design ANOVA (Rate of change × Delay information × Block), was used to determine main effects of the factors on response latencies and any interactions. The analysis excluding block showed no main effects of either the rate of change, $F(1, 36) = 0.32$, $p = .57$, or the provision of delay information, $F(1, 36) = 2.20$, $p = .15$. With block included in the ANOVA, the Greenhouse-Geisser correction had to be used because the data violated the assumption of homogeneity of covariance. However, even with these more conservative degrees of freedom, the analysis showed a main effect of block, $F(1, 36) = 23.90$, $p < .05$. A series of paired t tests revealed a significant decrease in latencies between blocks 1 and 2 and blocks 2 and 3, $t(39) = 4.05$ and 3.80 respectively, $p < .05$. These results compare favourably with the general trend revealed in Experiments 1 to 4. However, in contrast to Experiment 3, the provision of explicit delay information did not affect latency. It is possible that the effect of delay information was redundant in the current experiment because the relatively large incremental changes were easy for the participants to detect.

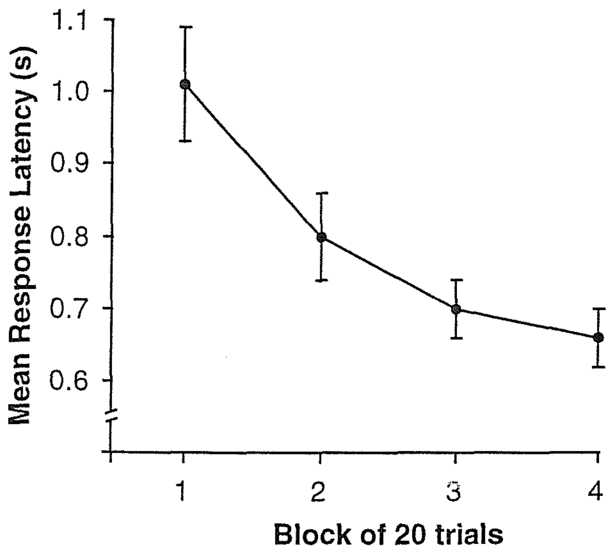

Figure 9-6. From Pepperell, Remington, and Warry (2000), Experiment 1. Mean response latencies per block of 20 trials. One standard error is shown above and below each point.

The second experiment conducted by Pepperell et al. (2000), focusing on the provision of previous choice information and performance information, found 22 of the 64 participants expressed a preference for the global choice, and 19 of these reported rules that approximated the local-global contingencies. A t test showed that the 19 globally aware participants made significantly more global (B) responses ($M = .68$, $SD = .14$) than the 45 unaware participants ($M = .36$, $SD = .18$), $t(62) = 7.04$, $p < .05$. A chi-squared test showed that there was a relationship between the provision of performance information and global awareness, $\chi^2(1, N = 64) = 9.06, p < .05$. Of the 19 globally aware participants, 15 (79%) were provided with performance information. Of the 45 globally unaware participants, 17 (38%) were provided with performance information..

Response latencies were collated for each participant, and means calculated for blocks of 24 trials (Blocks 1 - 4). A mixed-design ANOVA (Previous choice information × Performance information × Block), was used to determine main effects of the factors on response latencies and any interactions. The initial analysis, excluding block, violated the assumption of homogeneity of variance and so Box's correction was used to modify the degrees of freedom. There was no effect of previous choice information, which may indicate that participants did not use this information, $F(1, 31) = 0.95, p > .05$, but even with the more conservative degrees of freedom, the analysis revealed a significant main effect of performance information, $F(1, 31) = 4.82, p < .05$. This main effect is shown in Figure 9-7. A *t* test showed that the mean response latency of those participants provided with performance information was shorter than those without this information, $t(62) = 2.21, p < .05$. With block included in the ANOVA, the Greenhouse-Geisser correction had to be used because the data violated the assumption of homogeneity of covariance. However, in contrast to the initial decline in response latencies found in all preceding experiments, there was no effect of block, $F(1, 60) = 2.64, p = .11$. Also, although there was a main effect of performance information, there was no interaction of this factor with block, $F(1, 60) = 2.48$, $p = .12$. It might have been that this lack of effect somehow resulted from of the regular interruptions (every 12 trials for the display of information) in the normal choice procedure. However, testing such a hypothesis would require further experimentation.

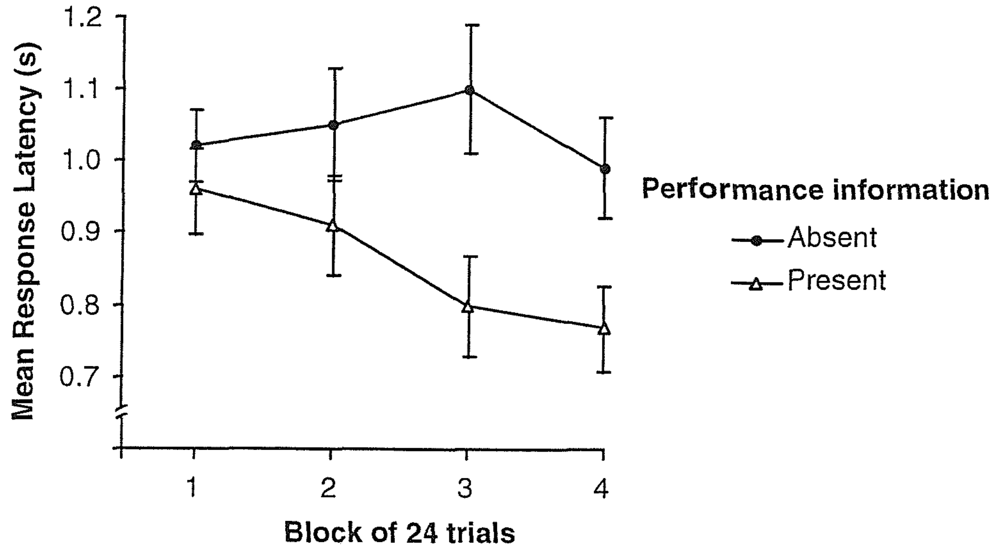

Figure 9-7. From Pepperell, Remington, and Warry (2000), Experiment 2. Mean response latencies per block of 20 trials for conditions with performance information present and absent. One standard error is shown above and below each point.

9.3 Global Maximisation from Rule-governed Behaviour?

It was a consistent finding of the experiments reported in this thesis, including the earlier studies discussed in chapter4 that, when exposed to the local-global conditions arranged by the Herrnstein procedure, participants performed poorly in terms of maximising global reward. Two-thirds (245 / 372, 66%) of the total number of participants who took part in the experiments reported in this thesis (including those of Pepperell et al., 2000), chose the local reward on more than 50% of the trials. However, when additional information (i.e., prospective information, social comparison information, explicit delay information, contingency descriptions, and performance information) was available or when conditions were simplified (i.e., when the averaging windows were reduced to one or two trials in Pepperell et al.), then task performance was improved. The most reactive of these factors were the provision of contingency descriptions (Experiment 4) and the rate of change condition, that used an averaging window of one trial (Pepperell et al.). Under these two conditions, the majority of participants (26 / 36, 72%) chose globally on more than 75% of the trials. One question that remains to be addressed is why any of these manipulations promoted global maximisation?

There is extensive empirical evidence that suggests that the performance of adult human participants in operant experiments is best considered as rule-governed as opposed to contingency-shaped (Bentall et al., 1985; Catania, Shimoff, & Matthews, 1989; Horne & Lowe, 1993; Lowe, 1979). The importance of following verbal rules with regard to task performance under the traditional SS versus LL model of self-control has also been frequently discussed (e.g., Logue et al., 1986; Mischel et al., 1989; Solnick et al., 1980). Although no firm conclusions are possible because verbal protocols were only collected post-hoc, the weight of evidence from the experiments of this thesis suggests participants used a rule-based response strategy. If so, this raises questions regarding the provenance of such rules.

Skinner (1969) has provided a detailed description of the differences between rule-governed and contingency-shaped behaviour. He argues that when analysing behaviour in the absence of rules two factors need to be taken into account, (1) the system that establishes the contingencies of reinforcement, and (2) the behaviour that is shaped and maintained by these contingencies. When the possibility of control by rules is introduced, two additional factors must be considered, (3) the rules extracted from the contingencies that describe relationships between events, responses and consequences within the system, that may either be self-generated or learnt from another member of the verbal community (Baum, 1995b; Skinner, 1969), and (4) the behaviour that results from following these rules. It was Skinner's opinion that the topography of behaviour governed by rules will probably never be identical to the behaviour that is purely contingency-shaped, because extracting a rule is a complex behaviour in itself and it is therefore unlikely that a rule will ever completely capture the nuances of the contingencies. "The behavior evoked by a rule is often simpler than the behavior shaped by the contingencies from which the rule is derived. The rule covers only the essentials; it may omit features which give contingency-shaped behavior its character" (Skinner, 1969, p. 167). This general framework, originally proposed by Skinner, will be used to guide the following discussion.

There are two possibilities that might explain rule use in the local-global paradigm. If participants extracted rules from the contingencies of reinforcement inherent in the Herrnstein procedure, then factors that promoted global choice may have operated by facilitating the formulation of rules which accurately characterised the local-global contingencies and / or identified the optimal response strategy without specifying the contingency.

As an example of the former, an accurate rule, could have taken a form such as, "being moderate pays off better in the long-term." However, it is conceivable that the majority of participants may have formulated defective rules in relation to the contingencies (e.g., alternating pays off better in the long-term"). For example, analysis of the questionnaires in Experiment 1 revealed that only 7% (8 / 112) of the participants could accurately describe the experimental contingencies. Of the remaining participants, 41% (46 / 112) described rules that partially described the contingencies but which identified either exclusive choice of the local reward or alternating as the optimal strategy, while 52% (58 / 112) declined to described any rules that they may have followed.

The second possibility is that factors that promoted global choice did so by providing feedback that indicated the worth of a particular response strategy and allowed participants to form rules relating to it. For example, in the second study by Pepperell et al. (2000), a rule that would have the effect of maximising global reward could be, "choose the small reward because the experimenter provides positive feedback." Thus, by providing positive and negative cues as to the success of the current response strategy (e.g., social comparative information in Experiment 1 and performance information in Pepperell et al.'s second experiment), effective global behaviour could be established without the need for awareness of the global contingency per se. As Skinner (1969) has pointed out, when following rules it is not necessary to "know" precisely why a particular response is beneficial.

The two possibilities of the use of rules described above can be considered in relation to the classification of two of the types of rule-governed behaviour proposed by Zettle & Hayes (1982): *tracking* and *pliance.* Tracking occurs when a rule is followed because of the apparent correspondence between the rule and the contingencies of reinforcement. For example, in the first possibility discussed above, following rules such as "being moderate" or "alternating" could be seen as tracking. This interpretation relies on the idea that when confronted with novel problems participants have in the past generated verbal rules which, when followed, produce a satisfying outcome. Pliance occurs when a rule is followed because of the socially mediated consequences for behaving in accordance with the its prescription. For example, following a rule such as "choose the small reward because the experimenter provides positive feedback" could be seen as pliance. This interpretation is an acknowledgement that participants frequently respond to experimental demand and the implied contingencies associated with it. It is possible that participants may have been complying with a perception of what the experimenter expected of them (i.e., to choose the immediate large one), and it would seem not unreasonable that suggest that many instances of everyday self-control may result from this sort of social reinforcement.

Before ending this discussion, however, it is important to note that the distinction between pliance and tracking does not lie in the specific construction of the rule but rather in the functional characteristics of the rule-following behaviour. A particular rule could equally act as a *ply* or a *track*, depending on the person's history of reinforcement with rule-following. For example, in Experiment 4, one group of participants were given a verbal description of the contingencies, including a statement (a rule) of the optimal response strategy. If the participant followed the rule because of a history of reinforced compliance in similar situation then the rule functioned as a ply. On the other hand, if the participant followed the rule because in the past, following similar rules had led to reinforcement that was not specifically mediated by the rule-giver then the same rule would have functioned as a track.

It is clearly necessary to establish the extent to which task performance is purely contingency-shaped or rule-governed. Unfortunately, none of the experiments conducted for this thesis were explicitly designed to address this question. It is arguable that prior to (or in the absence of) accurate rule formulation, participants' patterns of choices were shaped directly by the contingencies or, in cognitive terms, were reflections of implicit rather than explicit knowledge (Berry & Dienes, 1993). Given some similarities between the present task and the complex machine tasks often used in the study of implicit learning (e.g., Berry & Broadbent, 1984) it would be worthwhile to incorporate more rigorous assays of the implicitness of task knowledge (Shanks & StJohn, 1994) into future research. In addition, it would certainly be possible to improve the way in which protocol data are collected within the present paradigm. The questionnaires used to assess the participants' knowledge of the contingencies changed little between the four experiments, although the analysis was simplified after Experiment 1 to improve inter-rater reliability. In addition to collecting protocol data at the end of the session, it could be informative to chart the development of a participant's awareness of the contingencies, either by collecting verbal reports at intervals throughout the session or requiring the participant to "speak their thoughts" onto tape as they made their choices (see Ericsson & Simon, 1993). Such data could then be directly related to task performance. As an additional or alternative measure, it has been suggested that the pattern of shortening and then stabilising response latencies in these experiments (cf., Pepperell et al., 2000) may reflect the early formulation of rule-based response strategy, even though the rules may not necessarily reflect the optimal strategy. This could be established by using a multiple-base-line design, such that rule based information was provided at different times for different participants.

Given that by the end of the experiment most participants continued to choose the larger reward more frequently than the smaller, we can conclude that (1) experience of the global contingency alone was not sufficient to shape optimal behaviour, (2) that participants had failed to generate a verbal formulation that adequately described the outcome of global choice, or (3) that despite having done so, they were unwilling or unable to implement it. Any such failure to make effective use of explicit rule-based knowledge could have come about because the incentive value of the reward was sufficiently powerful to provoke selection of the larger local reward "against participants' better judgment" or because uncertainty about the stability of the conditions led to occasional tests of the current strategy.

9.4 Individual Differences

Notwithstanding the effects of the experimental manipulations on participants' choices, the experiments in this thesis provided evidence of considerable intersubject variability within conditions. As previously indicated, it is beyond the scope of this account to explain these individual differences in self-control, although some of the variability is undoubtedly the result of the participants' history of reinforcement. It has been empirically shown that self-control in pigeons can be promoted by exposure to a fading procedure in which the delay preceding the LL reward is gradually increased over an extended period (1 year; Mazur & Logue, 1978). In some respects, perhaps this reflects the evident differences in people's self-control in everyday life. Given the importance of historical factors, it is possible that the group-experimental designs used in this thesis and the previous studies cited in chapter 3, may obscure some interesting characteristics of an individual's behaviour that only a single-case experimental designs (see Hersen & Barlow, 1976) could reveal. For example, Ainslie and Gault (1997) argued that Rachlin's (1995a) model could not account for why a person who has achieved self-control (i.e., is globally aware) should occasionally backslide into impulsiveness. A single-case design could be used to address this issue. Once a participant has achieved a stable level of global maximisation, potential "temptation" factors could be manipulated to determine if participants could be induced to return to a suboptimal pattern of responding, despite having demonstrated behaviourally that they "know better".

9.5 Methodological Issues

The six experiments reported in this thesis and all the previous studies reported in chapter 4 have all utilised students, especially psychology students, as participants. It must be considered that the performance of students may be different from that of the general population, particularly if performance is strong influenced by social factors (i.e., results from pliance). The relationship between a psychology student and an experimenter, who may also be a tutor, is likely to be qualitatively different to that between an experimenter and a non-student. Studies using a non-student population would certainly be a useful addition to the literature.

Another factor that needs to be address is the issue of session duration and/or the number of trials. Sessions in Experiments 1 and 2 consisted of 200 trials while in Experiments 3 and 4 sessions consisted of 80 trials. These numbers were considered by the experimenter to be the maximum the participants would happily complete before becoming frustrated with the procedure. Whether all participants would eventually choose globally if given a sufficient number of trials is unclear but length of exposure to the contingencies should definitely be an important design consideration in further research.

9.6 Comparative Research Issues

The traditional SS versus LL model of self-control is generally discussed in the literature as if it were equally applicable to humans and non-humans alike (e.g., Logue, 1988). This is despite the fact that the strongest supporting evidence for this theory has been derived from studies of non-human subjects (e.g., Ainslie, 1974; Rachlin & Green, 1972) and the results of those that have used human participants have been much less convincing (Solnick et al., 1980; Sonuga-Barke et al., 1989a, 1989c). These apparent differences in the behaviour of humans and non-humans could be seen as evidence that a unified theory of self-control is an inappropriate goal. Alternatively, it could be argued that such differences are simply the result of inequalities in human and non-human experimental designs. As previously noted in this thesis, self-control studies using non-humans typically involve the use of primary reinforcers (i.e., food), whereas human studies use conditioned reinforcers (e.g., points and money), and the data collection period in non-human studies is usually considerably longer than the average human studied. However, there is as yet insufficient evidence to determine unequivocally which of these points of view is correct.

In comparison, the relatively small number of investigations employing the Herrnstein procedure have almost exclusively used human participants, and so offer little direct evidence for or against a unified theory of self-control. Nevertheless, one of the conclusions of this thesis, that the formulation of verbal rules is a significant factor of performance, suggests that trying to understand self-control in humans by studying the behaviour of non-humans may turn out to be a fruitless avenue of investigation. To resolve this issue, more direct comparisons of human and animal behaviour under the Herrnstein procedure, like the studies reported by Sokolowski (1996, 1998), are clearly necessary.

9.7 Conclusions

Humans and animals must frequently choose between rewards that occur at different points in time. Traditionally, choosing a larger but more delayed reward over a smaller but more imminent reward has been interpreted as self-control; the alternative choice as impulsive (Ainslie, 1974; Rachlin & Green, 1972). Evolutionarily, behaving impulsively may have been advantageous but in the modern environment such behaviour is usually maladaptive (Logue, 1995b). This thesis has examined an alternative model in which self-control is defined as maximising global reward over local reward, even if that involved choosing a relatively smaller immediate reward over a relatively larger immediate reward (Rachlin, 1995a).

Empirical research has indicated that people are generally insensitive to the contingencies of global choice and thus fail to maximise reward. However, the provision of certain types of information has been shown to promote global maximisation. It would seem information can have this effect because it widens the context to of the choice situation, making the local-global contingencies more salient. This may allow participants to formulate more accurate rules.

The final question that must be addressed is whether Rachlin's (1995a) local versus global model of self-control should be seen as replacing or simply complementing the traditional SS versus LL model. Rachlin's criticisms of the traditional model are convincing, and his re-casting in terms of local and global rewards does seem to better reflect many of the everyday situations seen as self-control. However, if as the experiments in this thesis show, the contingencies are insufficient to shape global maximising behaviour, then self-control may additional involve an ability to follow rules (Malott, 1989; Skinner, 1969). Such rules presumably frame the self-control choice as one between a SS and LL reward, as in the traditional model, even if the underlying contingencies are better described by Rachlin's local-global model. Abandoning the traditional model would therefore seem premature, but Rachlin's model may also have much to offer if we are to further develop our understanding of self-control.

Example Output from Experimental Programs

The sample text file represents output from 5 participants in a experiment that required each to make 15 responses. Data from each participant begins on a new line and finishes with the word "End".

The data (separated by commas):
•Group number
•Particiant number
•Button resulting in an A response (i.e., left button = LA, right button = RA)
•Number of trials in session
•Participants final reward (in this example, pounds sterling)
•Total number of A response
•Record of the participant's responses
•Response latencies (each separated by a comma)
•Participants pay-offs from each response (each separated by a comma).

```
1,1,LA,15,2.01,9,"ABBBAAABBAAAAAB",0.8,0.6,0.9,0.7,0.7,0.8,1.0,0.6,1.1,0.8,0.7,1.0,0.7,0.7,0.6,12,17,17,15,10,10,12,17,17,10,12,12,14,14,21,End.
1,2,LA,15,2.12,7,"ABBBAABABBAABAB",1.2,0.9,0.9,1.0,0.8,0.7,0.8,0.8,0.8,0.6,0.6,0.9,0.8,0.7,0.7,12,17,17,15,10,10,17,10,17,15,10,10,17,10,17,End.
3,1,RA,15,2.40,7,"AABABABABABBABB",0.6,0.5,0.4,0.7,0.7,1.9,3.3,0.5,0.9,0.9,0.7,0.6,1.0,0.9,0.7,12,12,23,12,23,12,17,12,17,12,17,17,6,17,11,End.
3,2,LA,15,2.35,8,"BABAABABBAABABA",0.8,1.0,1.3,1.9,1.4,1.1,1.7,1.3,1.7,4.8,1.9,2.0,1.4,1.2,1.5,17,6,17,6,12,23,12,23,17,6,12,17,12,23,12,End.
2,1,LA,15,2.05,8,"ABABAABABBABBAA",1.7,0.9,0.8,0.9,0.5,0.7,0.4,0.6,0.8,0.4,0.5,0.7,0.5,0.6,1.0,12,17,12,17,12,12,21,12,21,17,12,17,13,8,8,End.
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Appendix B

Questionnaires

Experiment 1

1. Looking at the whole task, which button was it best to press? Explain why you chose that button.
2. Did you figure out any rules which told you how the points on the left and right buttons were changed from choice to choice?
3. If you could only press one button throughout the task, which button would you press to get the highest score?

Experiment 2

1. If scoring points was important to you, can you describe how you tried to maximise your earnings.
2. If you could only press one button throughout the task which would you press and why?
3. Imagine you had to explain to a friend the best way to score points. What would you say and why?
4. Did you figure out any rules which told you how long you would have to wait to score a point from a left and right choice? Can you describe them.

Experiment 3

1. If earning money was important to you, can you describe how you tried to maximise your earnings.
2. If you could only press one button throughout the task which would you press and why?
3. Imagine you had to explain to a friend the best way to earn the most money. What would you say and why?
4. Did you figure out any of the rules which told you how long you would have to wait following a left and right choice? Can you describe them.

Experiment 4

1. If earning money was important to you, can you describe how you tried to maximise your earnings.
2. If you had to press one button for all 80 choices which would you press and why?

3. Imagine you had to explain to a friend the best way to earn the most money on this task. What would you say and why?
4. Did you figure out any of the rules which told you how long you would have to wait following a left and right choice? Can you describe them.

Appendix C

Raw Data

Experiment	Tables	Pages
1	C-1 to C-8	204 - 207
2	C-9 to C-11	208 - 209
3	C-12 to C-17	210 - 212
4	C-18 to C-20	213 - 215

Table C-1

Study 1: Responses made by participants in Group 1 (Differential +3, No Prospective information, No Comparison information)

Subject	Score	Proportion of A responses	Responses
1	864	0.18	[illegible]
2	753	0.095	[illegible]
3	1065	0.325	[illegible]
4	906	0.215	[illegible]
5	1499	0.635	[illegible]
6	1027	0.305	[illegible]
7	1281	0.485	[illegible]
8	942	0.25	[illegible]
9	779	0.11	[illegible]
10	982	0.255	[illegible]
11	902	0.2	[illegible]
12	1257	0.465	[illegible]
13	1284	0.485	[illegible]
14	709	0.06	[illegible]
M	1017.9	0.29	
SD	233.75	0.17	

Table C-2

Study 1: Responses made by participants in Group 2 (Differential +3, No Prospective information, Comparison information)

Subject	Score	Proportion of A responses	Responses
1	868	0.185	[illegible]
2	1070	0.325	[illegible]
3	1837	0.905	[illegible]
4	934	0.23	[illegible]
5	1830	0.9	[illegible]
6	861	0.19	[illegible]
7	1106	0.36	[illegible]
8	1392	0.575	[illegible]
9	1354	0.56	[illegible]
10	821	0.14	[illegible]
11	841	0.16	[illegible]
12	1151	0.385	[illegible]
13	1662	0.78	[illegible]
14	1487	0.655	[illegible]
M	1229.6	0.45	
SD	366.21	0.27	

Table C-3

Study 1: Responses made by participants in Group 3 (Differential +3, Prospective information, No Comparison information)

Subject	Score	Proportion of A responses	Responses
1	1229	0.455	BBAABBBBABBABBAABBBBAABBABBBABBBBABBBBABBBAABBABBABABBABABBABABAABBBABBBABBABBBABBBBBBBBBBBBBBBBBBBBABBBBBBBBABBBBBBBABBBBBBABABBBBABBBAAAAAAAAAAAAAAAAAAAAAABBBBAAAAAAAAAAAAAAAAABABAAAAAAAAAAAABBBAABBAAABBBBBAAAAAAABB
2	1338	0.545	BBABBAAABBABABBAABBBBBAAABAABAABABAAAABBABBBBABAAAAAAABBBBABAAAAAAAABBAAABABBBBBAABBBBBABAABBABAABBABBBABBAABBBBBABBABBAABBBBBABBBBAABBBABAABABBBBAAABBABBBBBBAAAAAABAABBBAABBAAABBAABBBAABBAAABBABAAAAABAAAAAAABAAABAAAAAAAAAAAABAAAAAAAABAAAAA
3	1179	0.435	BBBBBBBBBBBBBBBBBBABBBBBBBBABAABBBBABBABAAABBABBBABBAAABBABBABBBABBAAABBBBBABBBAAABBABBBBBAAABBBBBBABAAABBBBBBBAAAAABBBBBBBAAAAABBBBBBBAAAABBBABBBAAAAABBBAABBBAAAABBBABBBAAAABBBBBBAAAAABBBBBBAAAAAAABBBBBAAAAAAABBBBAAAABAAAAABBAAAAAAAAAAAA
4	625	0	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
5	1214	0.46	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABBBBABAAABAABBBBBBBBABABABABABABABBBAABBABABABABBBAABBAAAABABAAAAABBABBAAAABAAAAAAABBAAABAAABAAAABBAAAAAAABAAAAAABBAABAABAAAAAAAAAAABAAAAABAAAAAAAAAAAA
6	1395	0.58	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABABAAAABABABAABAABBABAABAABAABBABAABAABAABABAABAAAABAABBABBAABBAAAABBAABBBAAABBBAAAABABAAAABBBAAAABABAAAABAAAAAAABBAAAAABBBAAAABAAAAAABBAAAAABAABBBAABBAAABAABBBAABBAAAAAABAABBABAABAAAAAAAAAAAAAAAAAABAABBAAAABAAAAAAB
7	625	0	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
8	995	0.28	BBBBBBBBBBBBBBBBBBBBBSABABBABABBABAABABBABBABBBABABBABABABBBABABBABABBABABABBBBBBABABBABBBABBBABBABBABBABBBABBABBABBABBABBBABBABBABBBBBBBBBABBABABBABBBBABBABBBBABBBABBAABBBBBBBABBAABBBBBBBBABBBABBBBBABBABBABBABBABBABBABBABBBABABBABBABBA
9	1718	0.82	AABAABBBABABAABABBABABABAAAAAAAABABBAABAABABBBAAAAAAAAABBBAAAAAAAAAAAAAAAAAAABAAAAAAAABBBAAAAABBAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAABBABAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAABAAABAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAA
10	919	0.225	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABBABABBABABABBBABBABBABABABBBABBBBBBBBABBBABBBABABBBBBBBBBAABBBBBBBBBAABABBBBBBBBBBBBAABABBBBBBBBBAABBBBBBBBBBBAABBABBABBBAABBABBBABBABBBABBBBBBBABBBBBBABBBBBBABBBABBBABBABBABABBBABABBBABBBBBBBABBBAABBABBBA
11	625	0	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
12	800	0.125	BAAABABBBBABBBBABBBABBBBABBBBBBBBBBBBBBBBBABBBABBABBABBABBBBBBBBBBBBBABBBBBABBBBBBBBBBBBBABBBBBBABBBBBBBBBBBBBBABBBBBBBBBBBBBBABBBBBBBBBBBBABBBBBBBBBBBBBBBBABBBBBABBBBBBBBBBBBBBABBBBBBBBBBBBBBBBBBBBBABBBBBBBBBBB
13	632	0.005	ABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
14	1245	0.47	AAAAAAAAAAAAAAAAAAAAAAAAABBBBBBBBBBABBBAABBBBABBBBBBABBBBBBBBBBABBBBBBBBBAAABABABABBABBBABBBBBBBBBAABBBBBBBBBBBAABBBBBAAABBBAAABAABBABBBBBBAAAABABABBABAABBBAABBABAABABAABBBBAABBABAABABAABABABABABAABABABABABABABAABAAABABABAABAAAAB
M	1038.5	0.31	
SD	346.32	0.26	

Table C-4

Study 1: Responses made by participants in Group 4 (Differential +3, Prospective information, Comparison information)

Subject	Score	Proportion of A responses	Responses
1	1066	0.33	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABABABABABBABAABBABABABABABAABBABABABABABABABABABBABABABBABBBBABAABBABBABABBABBABABBABBABBBABABBABBABBBABBBABBABBABBAABBBBBBABBABBBBBBBABBAABABBBBAABABBAAABBAABABBAAABBABBABBABAABAABABBBBAABABABABBBBAAABBABBBBBAAABB
2	1462	0.615	BBBBBBBBBBBBBBBAAABBBBAAAAABBBBABBAABAABABABBAABBAAABABBAABBAAABABBAAAAAABBAAABABAAAAABAAABBAAAABBAAAAABAABAAABBAAABBAABAAABBAAABAAABAABABAABBAAABABBAAAABBAAAAAABAAABAAABAAAABAABAAABAAAABAAAABAAAABAAAABBBAAAAAABAAAAABBBAAABAAAAAAABBBAB
3	1634	0.76	BBBBBBBBBBBABABABABABABABBABAAABAAABBABAAAAAABABABAAAAABAAAABABABAAAAABABAAABAAAAABAABAAAAABAABAAAAAABAABAAABAAAAABAAAAAAABAAAAABAAAAABAAAAAAAABAAAAABAAAAAAAAABAAAAABAAAAABBAAAAAAAAAAAABBAAAAAAAAAAAABAAAAAAAABAAAAAAAAAAAAAAAAAAAABAAAAABAAAAAAAAAAA
4	625	0	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
5	1641	0.765	BBBBBBABBBBBBAAAABBBBBAABABBAABBBBAABBAABBABABBABAABBAAABABABBABAABBAAAAAAAAABBBAAAABAAAAAAAAABABAAAAAAABAABAABAAAAAAAAAAABAABAAAAAAAAAAAAAAAAAABAAAAABAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAA
6	1361	0.565	BAAAAAABBBABBABBBAABBBBABBBBBAABBBBBBBBBBBAABBBBBBBBBBBAABBBBBBBBBBBBABBBBAAAAAABBBBBAABBAAAABBBBBBBBBABBBBAAAAAAAAAABBBBAAAAAAAAAAAAAAAAAAAAAAAAABBBAAABBBBAAAAAABBBBBBBAAABBBBBBBBAAAAAABBBBBBBAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
7	1091	0.345	AABABBBBABBABBBBABABBBBBBBBBABABBABABABABBBBABABBBBBBBBBBABABBBBBBBBBBAABABBBBBBBBBAABBBBBBBBBBBABBAABBABBABABAAAABBABBBABABABAAAABBABBBBBABBABABBBBABBAAAABABBBBBAABABBBBBBBBABBBBAAAABABBBBABBBBAAAABABBABABAAABBBABBABABAAABBBABABABBBAABBAABBBABAABBB
8	1359	0.55	AABBBAAABAAABBBBAAAAAABBBBAAAABAABBBBAABAABBBBAAABABBBAAABBBBAAABABBBAAAAABBAAAABBBBBAABAABAAAABBBBBBBBABBBABBBABBAAABAAABABBBABBBAAABAAAABBABBBAABABABABAABAAAABABAAAAABBABBAAABABAAABAABBBAAABABAAABAABBBAAAAABAABBBBAABBAAAAABBBAABAAAAABABABAAABBAA
9	1423	0.595	BBBBBBBBBBBBBBABBBABBBBABABBABBABBBAAABABBABABAABBAAABBBAABABAABBAAABBBAABAAAABBBBBABAABAAAAAABBBAAABAABAAAAAABBAAABAABAAAAAABBAAABAABAAAAABAABAAAAAABBAAABAAABAAABABAABAAAABBAAABAABAAAABBAAABAABAAAAAABABAAAAAABAAABBAAAABAABAAABAAAAABBAAAABAAABAAB
10	932	0.225	ABBBBBBBBBBBBBBBABBABBBBBBBBBBBBBBBBBBBBBABBBABBABBABABBBBABBABBABABBBBBABBBBABABABBBBBBABAABBBBBABBBBABABBBABABBBBABBBBABBABABBBBABBBBABAABBBBBABBBBABABBBBABBBABAABBBBABBBABAABBBBABABBBBBBAABBBBBBBBAABBBBBBBBBBBBBAABBBBBABBBABBBB
11	1208	0.45	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABABABBBBBBBBBABABABABABBABBBABABBBBABABABBBBBBABBABBABBBBABAABBAABBABBBBABAABBAAABBAAAAAAABBABAAAAABBBAAABBAAAAAABABAAABBAAAAAABBAAAABBAAAAAAABBAABBAAAAAAABAABBAABAAAABABBAAAAAAAAAAAAAAAAAABAA
12	935	0.23	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAABBBABBBBBBBBBABBABABABBABABABBABABABABABABABABABABBBABBBABBBBABABABABABAAAAABABABABABAAAAABABABABABBAAABABBBBBBBBABABBAABBBBBBABBBABABABBBBBBA
13	1507	0.665	BBBBBBBBBBBABABABABABABABBABABBAABAABAABBBAAABAABABBABABAAABAABABBAAAABAABAABAABABAABAABBAABBAAAABABAAAABAAABAAAABAAABAAAAABABAAAAAAABAAAABAAAAAAABAAAAAAABAAAAAAABAAAAAAAABAAAAAAAABAAAAAAABAAAAAAAAABABAAAAABAAAAAAABAAAAA
14	1147	0.395	BABBBBBBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABABBBBBBBABABBBBBABBBBABABBBBBABBAABBABABBABBABABABBBABABBABBABABABABBABBABBABABABABBABBABBBBABAABAABABAABABAAABABBABBAAABBBABABAAABABAABAABABAAABABAABAABABABABAABABABAABAABABABABAABAABABBAABAAAAABABAB
M	1242.2	0.46	
SD	294.45	0.22	

Table C-5

Study 1: Responses made by participants in Group 5 (Differential +7, No Prospective information, No Comparison information)

Subject	Score	Proportion of A responses	Responses
1	1452	0.045	[illegible]
2	1446	0.035	[illegible]
3	1502	0.145	[illegible]
4	1698	0.5	[illegible]
5	1455	0.05	[illegible]
6	1467	0.07	[illegible]
7	1437	0.02	[illegible]
8	1499	0.125	[illegible]
9	1711	0.505	[illegible]
10	1458	0.055	[illegible]
11	1446	0.035	[illegible]
12	1659	0.445	[illegible]
13	1449	0.045	[illegible]
14	1609	0.33	[illegible]
M	1520.6	0.17	
SD	101.74	0.19	

Table C-6

Study 1: Responses made by participants in Group 6 (Differential +7, No Prospective information, Comparison information)

Subject	Score	Proportion of A responses	Responses
1	1687	0.49	[illegible]
2	1508	0.205	[illegible]
3	1470	0.075	[illegible]
4	1478	0.18	[illegible]
5	1694	0.54	[illegible]
6	1536	0.22	[illegible]
7	1642	0.415	[illegible]
8	1542	0.285	[illegible]
9	1589	0.365	[illegible]
10	1458	0.055	[illegible]
11	1485	0.1	[illegible]
12	1524	0.165	[illegible]
13	1446	0.035	[illegible]
14	1452	0.045	[illegible]
M	1536.5	0.23	
SD	85.184	0.17	

Table C-7

Study 1: Responses made by participants in Group 7 (Differential +7, Prospective information, No Comparison information)

Subject	Score	Proportion of A responses	Responses
1	1425	0	[illegible]
2	1559	0.245	[illegible]
3	1532	0.22	[illegible]
4	1425	0	[illegible]
5	1672	0.45	[illegible]
6	1425	0	[illegible]
7	1479	0.15	[illegible]
8	1790	0.65	[illegible]
9	1700	0.515	[illegible]
10	1910	0.9	[illegible]
11	1706	0.525	[illegible]
12	1611	0.33	[illegible]
13	1521	0.21	[illegible]
14	1646	0.445	[illegible]
M	1600.1	0.33	
SD	146.74	0.27	

Table C-8

Study 1: Responses made by participants in Group 8 (Differential +7, Prospective information, Comparison information)

Subject	Score	Proportion of A responses	Responses
1	1650	0.425	[illegible]
2	1581	0.28	[illegible]
3	1746	0.6	[illegible]
4	1626	0.395	[illegible]
5	1793	0.705	[illegible]
6	1598	0.32	[illegible]
7	1704	0.53	[illegible]
8	1690	0.485	[illegible]
9	1805	0.65	[illegible]
10	1630	0.4	[illegible]
11	1584	0.275	[illegible]
12	1702	0.54	[illegible]
13	1486	0.175	[illegible]
14	1719	0.53	[illegible]
M	1665.3	0.45	
SD	88.619	0.15	

Table C-9

Study 2: Responses made by participants when the Differential was 3 seconds

Subject	Proportion of B Responses	Responses
1	0.46	ABBAABBAABAAABAABABAABABAABBABBAAABBABABBAAAABABBABAABABBBAAABBAAABAABABAABAABBBAABABBABABAAABABAABABABBAABABBBAAABABBBAAABABAABABBABABBAABAAABABABBAABBAABAABABABBAABABABABABABBABABABABABAABABAABABA
2	0.575	BABAABBABBBAABBABABAAABAAAABBABAAAABBBBBBBBBBAAAABBBBAABABBBBAAAAABABABAAAABAAABAAAAABAAAABBAAAAAABABBABABBAAAAAAAABBBBBBBBBBBBBBBAABBBAAABBBBBBBBBBBBBBBBBBBBBBBBBAABAABBAAAABBBBAAAABBBBBBABBBBBB
3	0.615	ABBAABABBAABBABBABABABBABABBABBABABABBABBABABABBABABABABABBABBBABBABBAABBBABBABBBABBABBABABBABBBBBBBABBBBABBBABABBBBABBBBABBABABABAABABBABBBBABABABABABABABBABBABABABABABABABBABBAABAABABAABBABBBABA
4	0.5	BBABAABBAABBABAABAABBAAABBABBBAABBABAAAABBBAABABAABAABABBABABBAABABABAAABABABBABBBAABABBABBAAAABABBABBABBAABABBABBABBAABAABABBABBAABAAABABABABABABBBABABABABBABBABAAABBABABABAAABBAAABBABABBAAABABABABA
5	0.505	BBBAAABBAABBBBAAAAABBBBBBAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAAAABAAABAAAAABBBBBBBBBBBBBBBBBBAABABABBBBBBBBBAAAAAAAAAAAABBAAAAABBABABAAABBBBBBBBBBBBBBBBBAAABAAAAAABAAAAAAAAABAAAAAAAAAAAAAAAAABBBABAAAAAAAAA
6	0.38	ABAAABAABAABABBBAABBAABABABAAAAAAAAABBABAAABABAABBAABAABAABAAAABAAABAAABABBBAABAAABABABAABBAABABAAAAAABBAABABABBABABBABABABABABAABABAABAAABABABABABAAAAAABAAAABABABAABAAAABBBBABAAAAAABABABAAABAABAB
7	0.085	BABAABAAAAABAAAABAAAAAAABAAAAAAABAAAAAAAABAAAAAABAAAAAAAAAAAABAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAABAABAAAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAA
8	0.02	AAAAABAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAA
9	0.065	ABBABBABAABAAABAAAAABAAAAAAABAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABBAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
10	0.565	BAAABBABABAABBBABBBABAAABAAAAABAAAABAAAAAABAAABAAAAAAAAAAAAAAABAAAAAAABAAAAAAAAAAABBAAAAAAAAAAAAAAAAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAABAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
11	0.425	BBAABABBBAAABBABBBABBAABAAAABBABBBAAABBBABBABABBABBBBAABBBBBAAAABBBBAAAABAABABABABAABBBBBBAAAAAAAAAAAAAAAAAAAAAABBBBAAAAAAAABBBBAAAAAAAABBABBBAAAAAAAAABBBBBAAAABABBAAAABAAAAAAAABBBBBAAAAAAAAABBBAAAAAAABBBB
12	0.06	BABABAABAAAABAAAABBAAAAAAABAAAABAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
13	0.225	AAAAABAABAABAAAAABAAAAABAAAAAABAAAABBAAAAAAABAAAAAAAABABAAAAABAAABAABAAAABBAAABAAAAAABAAAABBAABAAAAAABBAAAAAAAAAAAABBAABBAAABAAAABAABAAABBAAAAABAAAABBAAAAAAAABAABBBAAAAAABAAAAAAAAAAAABAAABAABABAAAABAABA
14	0.355	AAAAABAAABBAAAABBAAABAABAABAAABAABAAAABAAAAAAAABABABABAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAABAABBAAAAAAAAAABAABAABBAABBBABABAAABAAAABBBBBABBBABBAABBBBBBBABBABABBBBBABAAABBAABBAAABAABBBBBBBABAB
15	0.445	BAAABAABBAAAABAABABBABAAAAAAAAAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABBBBBBBBBBAAAABABABBBBBBBAAAAAAAAABBBBBAAAAAAAAAAAAAABBABBBAAAAAAAABAAAAAAABAABBAAABBAABBBAABBBBBBBBBAAAAAAAAA
16	0.51	BBBBAAABBAAABBAABBBABBBBBAAAAABAAAABBAAAAAABBAAAAAABAAAABBAAAAAABBAAAAAABBAAAAAAABBAAAAAAABAAAAAAABAAAAAAAABAAAAAAAAAAAAAABABAAAAAAAAAAAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
M	0.36	
SD	0.20	

Table C-10

Study 2: Responses made by participants when the Differential was 5 seconds

Subject	Proportion of B Responses	Responses
1	0.05	ABBABAAABBAABAAABABAAAABAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
2	0.03	ABAAABAABABAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
3	0.07	ABBAABBAABABABBABABBABAAAABAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
4	0.245	ABAABAABAAABAAABBAABAAAAABBAABAAAABABAAAABAAAABAAAAAAABAABAAABAAAABABABABABABAAAAAABBABAABABBBBBBAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABBBBBBBBBBBBBBBAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
5	0.135	BBAABAAABAAABAAAABAAAABAAAAAABAAAAAAABAAABAAAAAABAAAAABAAAAAABAAAAAABAAAAAAAAABAAAAAABAAAAAAAAAAABAAAAAAABABAAAAAABAAAAABAAAAAAAABAAAAAABAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAABAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAAAAABAAAAA
6	0.11	BABBABABABBABBBAAAAAABAAAAAAAAAAAAABABAAAAAAABAAAAAAAAAAABABAAAAAAAAAAAAAABABAAAAAAAAAAAAAAAAAAAAAAAABABABAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAA
7	0.085	AABBAABBAAAAAABAAABAAAAABAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAAAAABAA
8	0.385	BAABABABABABBAABABAABBAABBBBABBBABBABBAAAABAAABABABAAAABBAAAABBAAAAABAAAAAABBBAAAABABBAAAAAAAAAAABBAAAABBAABBABBBBBBBBAAAAAAAAABAABABBAAAAAABBBAAAAAABABBBAAAAABAAAABABBAAAAAAAAAAAAAAABABBBBAABBABABAA
9	0.155	AAAABBBBAAABBAABBBAAAAAAAAAABABAAABAAAABAAABAAAAABAABBAAAAAAAAAAAABAAAAABAAAAAAAAAAABAAAAABAAAABAAAAAABBBAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAABAAAAAAAAAAAAABBAAAAAAAAAAAAAAAAAABAABAAAAAAAAAAAAABAAAAAAAAAAAA
10	0.12	AABABABABBABBBAAAAAABABAAABAAAABAAAAAAAAABBBAAAAAAAAAAAAAAAABAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABBAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAA
11	0.13	ABBAAABBBBBBABBAAABBBBBAABBBABAAAABAAAAABAAAAAAAAABAABAAAAAAAAABAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
12	0.05	ABAAABAABABAAAAABAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
13	0.09	AABBBAAAAAAAAAAAAABAAAAAAAAABAAAAAAAAAAAAAAAAAAAABAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAABBBBBBBBAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAA
14	0.045	BABAABABAAABAAAAAAAAAABAAAAAAAABABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
15	0.02	AAABAAAABAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
16	0.17	BABBAAABBAAAAABAABAAABBBAAABBAABBBBABABABBABABBABABAAAAAAAAAABBABAAAABBBAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAA
M	0.12	
SD	0.09	

Table C-11

Study 2: Responses made by participants when the Differential was 7 seconds

Subject	Proportion of B Responses	Responses
1	0.29	AAABAAABAAABAAAABAAABAABBABAABBABAAAAABAAABAABAAABABABAABABAAAABAAAAAAAAABAAABAAAAAABBBAABAABAAABAAABABABBBAAABAAAABAABAAABBBAAAAAAAAAABBAAAAABAAAAABBAAAAABBBAABBAAAAAAAAAAAAAABBABBAAAAAAAABABAAABABBA
2	0.06	BABAAAABAAAAAABAAAAAABAAAABAAAAAAAAAAAABAAAAAAAAAABAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
3	0.025	ABAABBAAAABAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
4	0.97	AAAABBAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
5	0.055	AABBBAAABAAAABAAABAAAAABAAAAAAAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
6	0.33	AAABABAABABAAABABABAAAABAAAABBAABAAAABABBBBAAAAAAAAABAABAAAAAAAAAAAABBBAABAABABAAAAAAAAAABBAAAAAAAAAAAAAAAAAAAAABBBBBBBBBBBBBBBBBBAAAAAAABABAAABAAAAAAAAAAAAAAAAAAAAAAAAABBAAABAABBAAABBAABAABABBAABAAABAAABBBB
7	0.575	BAAABAABABAABBABBAAAAAABBABBBABBBABABBBBBBABBBBAAAABABABBABBBABABABBBBAABBBABABABBBBBAAABABBBBABABBABABABABABAAAABBABAABAABBBBBBABABBABABABBBABBBABAABABABBBABABABABABBABABABAABABABBABABBBABBABABBABBAB
8	0.05	BBBAAAABAAAABAAAABAAAAABAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
9	0.03	BBAAAABAAAAABAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
10	0.18	BABABABABABAABABABABBABABABBBBBBAAABAAAABBABABBAAAABBABABBABBBAAAAABAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
11	0.405	AABBABBAAABBAAABBABBAAABBAAABBBAABAABABAAAABBABBAABBAABBBABABABAAAAABBABBBAAAAAAAAABBBAAAABAAABBBABABABAAAAAAABAAAABBBABAAABBAABBAAAAAAABBBABAAABBBBABAABBBBBABABABAAAAABBABAAABBBAAAAAAAABAAABAABAAAAAAAAA
12	0.085	AABABBAAABAABBAAABAAAAAAABBAAABAAABAAAABAAAABAAAAAAABBAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
13	0.305	BAAABAAAAAABAABAABAAAAABAAABAABAABABAABAAAABAAAAABAAAABABAAAABAABAABAABBAAABAAABAAAAABAAABAAAABAAABAAABBABABBAABAAAAABAABAAAAABBAAAAAABABBAAAAAAAABABBAAAABABAAAAAAAAABBAABBABBAAABBABABABBBBABAAABAAAAA
14	0.27	ABABABABBAABABABABBABABABABBAABBABABAABABABABABBABABBABABABBABABABBABABAABBAAAAABBABBAABABABAAAAABAAABAAAAAAAAAAABAAAAABBAAAAAAAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
15	0.085	BAABBBABBABABAAAAAAAAAABAAAAAAAAAAABAAAAAAAABBABAAABAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
16	0.63	BABAABABABBABABBBBBBBBBBBBBBBBBBAAAAAAAAAABBBAAAAAAABBBBBBBBBBBBBBBBBBBABABABABABABABBBBBBBBBAAAAAAAAAABBBBAAAAAAAAAAABBBBBBBBBAAAAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAAAAAAAAABBBBBBABBBBBBAAABAAABBAABABAABABBBBB
M	0.27	
SD	0.26	

Table C-12

Study 3: Responses made by participants in Group 1 (Increment +2, No explicit delay information)

Subject	Earnings /p	Proportion of B responses	Responses
1	201	0.1375	ABBBAAABBAAAAAABAAABAAAAAAABAAAAAABAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAABAAAAA
2	287	0.3875	ABBBAABABBAABABABAAABBBBABABAAAABBAAABAAAAAAABBAAAAAAABABABAAABBBBAAABABAAAAAA
3	284	0.425	AABAAABAABBAAABBAAABAAABABABABABABAABAAAABBAABABABABBABABABABABAABABABABABABAB
4	277	0.4625	BAAABABABBAAABBABAABBBBBBBBBABAAAAAAAAABAAAABBAAABAABAAAAAAAAABBAAAABBBBBBBBBBB
5	218	0.175	ABAAABABABBAABBAAAAABAAABAAABAAAABAAAAAAABAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAA
6	209	0.1875	AABABABABAAAABAAABAABAAABAAAAABAAAAABAAAABAAAABAAAAAAABAAAAAAAAAABAAAAAAAAAABAAAA
7	272	0.3375	ABBAABAAABBABBBABAAAAAAAAAAAABABBAABABABABABAABBBABABABBAAAAAAAAABAAAAABAABAAAAA
8	170	0.0375	ABABAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
9	399	0.775	ABAABAAABBBAABBAAABBBBBBBBBBBBBBBBBBBABBAABAAABABBBBBBBBBBBBBBBBBBBBBBBBBBBB
10	190	0.1375	BAABAABAAAABAAAAAABAAAAAABBAAAAAAAAAABAAAAAAAABBAAAAAAAAAABAAAAAAAAAAAAAAAAAAA
M	250.70	0.31	
SD	64.06	0.21	

Table C-13

Study 3: Responses made by participants in Group 2 (Increment +4, No explicit delay information)

Subject	Earnings /p	Proportion of B responses	Responses
1	205	0.175	ABABAABABBABBAAAAAAAAAAAAAAAAAAAAAAAAAABBAABAAAAAAAAABBAAAAAAAAAABAAAAAAAAAAAAAAB
2	337	0.5375	AAABAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAAABBBBBBBBBAAAAAAAAAAAAAAAAAAAAAA
3	228	0.2375	AABABAABAAAAABBAABAABAABAABBABAAAABAABAAAAAABAAABAAAABAAAAAAABAAAAAAABAAAAAAAABA
4	330	0.5375	ABBBABAAABBABAAAAABBAABABABBABABABBABBBABBAABABABABABBABABABABABABBBBBBAABBAAABB
5	250	0.35	BAABAAABAAABAAAABAAABAAAAAAABAAAAAAAAABAAAAAAAAAAABAAAAAAAAABBBBBBBBBBBBBBBBB
6	232	0.275	BBBAABAABABBBBBBAAABABBAAAABAABAAAAAAABAAAABAAABAAAAAAAAAAAABAAAAAAAAABAAAAAABAA
7	394	0.7125	BABABBBAAABAAABAAABAAAABAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAABAAAB
8	184	0.1125	BABAAAABABAAAAAABAAAAAAAAAAAAAAAABAAAAAAABAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAA
9	191	0.1375	AAABAAABAAABAAAABAAAAAAABAAAAAAAAAABAAAAABABAAAABAAAAAAAAAAAAAAAAAAAAAAABAAABAAAA
10	206	0.1625	ABAABBBBAAAAABABAAAABAAAAAAAAABBBAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAA
M	255.70	0.32	
SD	68.55	0.20	

Table C-14

Study 3: Responses made by participants in Group 3 (Increment +6, No explicit delay information)

Subject	Earnings /p	Proportion of B responses	Responses
1	294	0.4625	AABABABABABBABBABABABBABBAABBAABAAABABABABABABABAABBAAABABABABABABABBABABAAAABAA
2	318	0.525	BABAABABBAABABABABABBAABABBBBABBABABABABABBABAABABBABABABBABABABAABABBABAAABBBAA
3	224	0.2375	ABBBABAAABAAAAABAAAAAABAAAAABAAAAAAAABABBABBAABABAAAAABAAAAAABAAAAAAABAAAAAAAABA
4	320	0.5	BABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABA
5	245	0.3	BABAAABAABAAABABAAAABAABAAAAABAAAABBBAABBAABAAAAAAABAAAAAABABAAAABBAAAABAABBAABA
6	262	0.3375	ABAABAABAAABAABAAAABAABAAABAAABAAABBAAABAABAABBBAAABAAABBAABABABBABAAAAABBAAAAA
7	370	0.6625	ABAABAABAAAABBAABBAABBAABBABBABBAAABBABAABABAABBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
8	213	0.2125	ABAABABAABAAABAAAABAAABAAAABAAAABABAAABAABAAAAABAAAAAABAAAAABAAAAABAAAAABAAAAAAA
9	190	0.1625	BAABAABBBAAAABAABAAAABAAAABAAAAAABAAAAAABAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAA
10	168	0.075	ABAAAAAAAABAAAAAAAABAAAAAAAAAABAAAAAAAAAABAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAA
M	260.40	0.35	
SD	61.09	0.18	

Table C-15

Study 3: Responses made by participants in Group 4 (Increment +2, Explicit delay information)

Subject	Earnings /p	Proportion of B responses	Responses
1	362	0.675	BBBABAAAAAAABAAAAAABAAABAAABAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
2	264	0.4	ABBBBAAABAAAAAABAAABAAABAAABAAAAAAAABAABABAAABAAABAAABAAAAABAAABABBBBBBBBBBBBBBB
3	190	0.1125	ABBABAABAAABAAABAAAABAAAAAABAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
4	204	0.125	BBAAABAAAABAAAABAAAAAAAAABAAAAAAAAAABAABAAAAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAAAA
5	328	0.5	BABABBAABBBBBBAABABABABBBAAAABBABBBBAABBBBABABBAAABAABBAABBABAAAAAABABBAAABAAAA
6	195	0.1375	BAAABAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAABAABABABAAABBBAAAAAA
7	188	0.0875	BAABAAAABABAAABAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAA
8	376	0.7125	BAABAABAABAABAAAABAABABAAABAABAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
9	442	0.9125	ABBBBBBBBBBBBBBBBBBBBBBAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
10	289	0.4875	BAAAABABAABBBAAAAABBAABBAABBABAAAABAABAABAAABAABAAAAABAAAABAABBBBBBBBBBBBBBBBB
M	283.80	0.42	
SD	86.17	0.28	

Table C-16

Study 3: Responses made by participants in Group 5 (Increment +4, Explicit delay information)

Subject	Earnings /p	Proportion of B responses	Responses
1	419	0.7875	ABAABAABAAAABAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAABAABBBBBBBBBBBBBBBBBBBBBBBBBBBABB
2	206	0.175	ABBAABAAABAAAAABAAAABAAAABAAAAAABAAAAAAABAAAAAAAAABAAAAABAAABAAAAAAABAAAAAAAAAAB
3	451	0.9	BAABAAABAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
4	337	0.5625	ABAAABBAAABBABBAAABBBBBBBBBBAAAAABBBAAAABBBABABABAAABABAAABBBBBBBBBBBBBBBBAAAABA
5	370	0.6625	AAABBAABAAAABAABABABAAABAABAAAAABBBBBBBBBBBBAAABBBBBBBBBABBBBBBBBBBBBBBBBBBBBBBB
6	197	0.175	AABAABAAABAABAABAAAABAAABAAAAAABAAAAAABAAAAAAABAAAAAAAABAAAAAAABAAAAAAABAAAAAAAB
7	202	0.1625	BBBAABAABAAAABAAAAAAABAAAAAAAAAAAAAABAAAAAAABAAAAAAAAAAABAAAAAAABAAAAAAABAAAAABA
8	308	0.475	BABABABABABABABABABABAAABAAABABABABABABABABABABABABABABABABABABABABABABABABABABA
9	232	0.25	BBAAABABAABBAABAAABAABAAABAAABBAABAAABAABAAAAAABAAAAAABAAAAAAAABAAAAAAABAAAAAAB
10	182	0.1125	BAAABAAABBAABAAABAAABAAAAAAAABAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAA
M	290.40	0.43	
SD	94.85	0.28	

Table C-17

Study 3: Responses made by participants in Group 6 (Increment +6, Explicit delay information)

Subject	Earnings /p	Proportion of B responses	Responses
1	395	0.7375	BAABAABBBABBAABABAABAABAAAABAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
2	211	0.2	BAAABABAAABAAAAABAAAAAABAAAAABAAAAABAAAAABABAAABAAAAAAABAAAAABAAAAABAAAAABAAAAAB
3	441	0.875	BAAABAABBBBBBBBBBBBBBBBBBBBBBAAABAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
4	374	0.675	AABAAABAAAAABBABBBBAABAABBBABBBBBAAAABABBAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
5	232	0.2625	AAABABAAABAABABAABBAAABAAABAABAAABABAAABAABAAAABAAAAABAAAAABAAAAABAAAAABAAAAAAB
6	215	0.1875	ABAAABAAAAABAAAAABAAAAAAAAABAABABAAAAABAAAABAAAAABAAAAABAAAAABAAAAABAABAAABAAAAA
7	438	0.85	BBBAABABAAABBAAAAABABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
8	270	0.3625	BAAABBAABBBAAABAABAABAAAABAAAAABABABABBAABBAABABAAABAAAAABABABABBAAAABAAAAAB
9	459	0.9125	AABABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
10	190	0.125	ABBAAABAABAABAAAAAAAAABAAAAAAAAAABAAAAAAAAAABAABAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAA
M	322.50	0.52	
SD	103.16	0.30	

Table C-18

Study 4: Responses made by participants provided with no additional information

Subject	Earnings /p	Proportion of B responses	Responses: Practice	Responses: Experimental
1	425	0.7375	BABAAABAABAABAAAAABB	BAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAABBBBABAAAAAAA
2	222	0.1625	BABAAAABAAAAAABAAAAA	ABAAAAABAAAAABAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAABAAAAAAAAAAABAAAAAAAAAAABBBBBBB
3	239	0.125	BAAABAAABABAABAAAABA	AAAABAAAAAAABAAAAAABAAAAAAAAAAAAABBBAAAAAAAAAAAAAAAAAAAAAABAABAAAAAAAAAABAAAAAAB
4	482	1	BABAAAABBBBBBBBBBBBB	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
5	351	0.5375	BBABBABABBBAAABAABAA	BABBAAABAAABAAABABABABABBABABAABBABABBABABABABABABBABABABABABABBABBABBABBABBABBB
6	349	0.55	ABBAABAABAAAABAAAAAB	AABAAAAAAAAABAAAAAABAABAAAABBBBAAABBBBBABBBBBBBBAABABBBBAABBBBBBBBABABABBBBABBBB
7	238	0.125	ABBBBAAAABAABAABAAAB	AAAABAABAAABAAAABAAABAAAAAAAABAAAAABAAAAAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAB
8	222	0.075	BAAABBBAAAAABAAAABAA	AAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAABAAAABAAAABAAAAB
9	233	0.0875	BBAAABAAAABAABAAAABA	AAAAABAAAABAAAAAABAAAAAAAAAAAABAAAAAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAAAAABAAAAAAA
10	238	0.1125	BABAABBABABABAABABAB	ABAAABAABAABAAABAAAAABAAAAAAAAAABAAAAAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAB
11	243	0.1125	BABABBABABBABBAAABAA	ABAAABAABAAABAAABAAAABAAAAAABAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAABAAAAAAAAAAAA
12	253	0.1625	BABBBBBAAABAAABABAAA	AABAAAAAAABAAAABAAAAABAAAAABAAAAAABAAAAAABAAAABAAAAAABAAAABAAAAAABAAAABAAAAAABAA
13	262	0.2125	ABAABAABAAAABAAAAAAA	AAAAABAAAAAAAAAABAABAAAABABAAAABAABAABAAABAAAABAABAAAAAAAAAAAABAABABAAAAAABAABAB
14	398	0.7375	BAAABAABAAABAAAAABAA	BAAAAAABAAAABAAAAAAAABAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
15	364	0.5875	ABAAABBAAABAABAAAABB	AABAABAAAABBAAAAABBBAAAAABBBBABABBABBBAAAABBAAABBABBBBBBBBBBBBBBBBBBBBBAAABBBBBA
16	391	0.7	AABBBAAAABAAAABAAABA	AAAAAAABAAAABAAAAAABAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
M	307	0.38		
SD	86	0.31		

Table C-19

Study 4: Responses made by participants provided with explicit rules

Subject	Earnings /p	Proportion of B responses	Responses: Practice	Responses: Experimental
1	426	0.8125	BBBBAABBBBBBBBBAAAAAB	BBBBBBBBAAAAABBAABBBBABBBBBBBBBBBAABBBBBBBBBBBBABABBABBBBBBBBBBBBABBBBBBBBBBBBABBBBB
2	417	0.8	BABBBBBBBBBBAAABABBBB	BBBBBBBBBBBBBBBBAABABBBBBBABBBABABBBBABBBABBBBABBABBABBABBBBBBBABBABBABBBABBBBBB
3	476	0.95	BABBBBBABBBBBABBBBBB	BBBBBBBABBBBBBBBBBBBBBBBBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAA
4	427	0.8125	BBAABAABBBBBBAAAABABB	ABBAABBAABBBBBBBBAABBBBBAABBBBBBBBBBBBAABBBBBBBBBBBBABBBBBBBBBBBABBBBBBBBBBBBAABBB
5	451	0.9125	ABABBAAAABBAAAAABAAA	AAAABAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
6	413	0.75	ABBBABAAABAAABBBABBB	ABBBBBBBBBBBBBABABBBBBAABBBBBBBBBBABBBBABBBABAAAABABBBBBBBBBBBABBBABBBABAAAABBBBB
7	466	0.95	ABBBAABAAABABAAABBAA	BBBBBBBBBBBBABBBBBBBBBBBBBBBBBBBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAABBBBBBBBBBBBBBB
8	480	1	BBBBBBBBBBBBBBBBBBBB	BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
9	467	0.95	BBBBBBBBABAABABBBBBB	BBBBBBBBBABABBBBBBBBBBBBBABBBBBBBBBBBBBBBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
10	396	0.725	BBABAABABBBBAABBBABB	BBBBBBBBBBAAABBBBBAAAAAABBBBBAAAAAAAABAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
11	475	0.9875	ABBBBBBBBBBBBBBBAABB	BBBBBBBBBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
12	249	0.15	ABABAAABAAABAAABAAAB	BBBAAAAABAAAABAAAAABAAAAABAAAAAAAABAAAAAAAAAAABBAAAAAAAAAAAAABAAAAAAAAAAAAABAAA
13	430	0.825	BAABAABAAAAABABAAABB	BBBBBBBBBBBBBABABBBBAABBBBBBBBBAAABBBBBAABBBBBBBABBBBBBABBBBBBBBAABBBBBABBBBBBB
14	474	0.975	BABABBABBBAAABBBBBBB	BBBBBBBBBBBBBBBBBBBBBBBBAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
15	468	0.9625	BBBBBBAABBABBBABBBBB	BBBBBBBBBBBBBBBBBBBBAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
16	461	0.9375	BABAABABAABABABBBBAB	BBBABBBBBBBBABBABBBBBABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBABBBBBBBBBBBBBBBBBB
M	436	0.84		
SD	57	0.21		

Table C-20

Study 4: Responses made by participants who experienced forced-choice

Subject	Earnings /p	Proportion of B responses	Responses	
			Practice	Experimental
1	256	0.1625	AAAAAAAAAABBBBBBBBBB	BBAABAABAAABAAAAAAABAAABAAABABAAAAABAAABAAAAAAAAAAAAAAAAABAAAAAAABAAAAAAAAAAAAAA
2	374	0.6	BBBBBBBBBBAAAAAAAAAA	BAABBBBBBBBBBBBBBBBAAAABBAABBBAAAAAAAAAAAAAAABBBBBBBBBBBBBAAAAABBBBBBBBBBBBBAAAA
3	391	0.7125	BBBBBBBBBBAAAAAAAAAA	AABABAAAABAAAABAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAABAABBBBBBBBB
4	437	0.8625	AAAAAAAAAABBBBBBBBBB	AAAAAAAAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
5	455	0.9125	AAAAAAAAAABBBBBBBBBB	ABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBAAAABABABBBBBBBBB
6	225	0.05	AAAAAAAAAABBBBBBBBBB	AAAAABAAAAABAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
7	472	0.975	BBBBBBBBBBAAAAAAAAAA	AABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
8	448	0.9	BBBBBBBBBBAAAAAAAAAA	ABAAABAAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
9	239	0.1125	AAAAAAAAAABBBBBBBBBB	ABAAAABABAAABAAAAAABAAAAAAAAAAABAAAAAAAAAAAAAABAAAAAAAAAAABAAAAAAAAAAABAAAAAAAAA
10	228	0.075	AAAAAAAAAABBBBBBBBBB	BAAABAAAAAABAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABABAAAAAAAAAAAAAAAAA
11	363	0.55	BBBBBBBBBBAAAAAAAAAA	BAABBBAAABAABBBBABABBABABBBABABBAABBBABABABBABABABAABBBABAABABABABABABABABABA
12	272	0.2125	AAAAAAAAAABBBBBBBBBB	BBAAABAAAAAAABAAABABAAAAABAAABAAAAAAABAAAAABAAAAAAAAAAABAAABABABABABAAAAABAAAAAA
13	398	0.725	BBBBBBBBBBAAAAAAAAAA	BAAAABAAABAABAAAABAAAAAABAAABBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
14	231	0.0875	BBBBBBBBBBAAAAAAAAAA	BAABAAAABAAABAAAAAAABAAAAAAAAAAAABAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAABAAAA
15	256	0.175	BBBBBBBBBBAAAAAAAAAA	ABBAABAAABAAABAAABAAAAABAAAABAAAAAABAAAAABAAAAAABAAAAAAAAAAABAABAAAAAAAAABAAAAAA
16	248	0.1375	AAAAAAAAAABBBBBBBBBB	ABAAAABAAABAAAAAAABAAAAAAAAAAAAAAABAAAAAAAAAAABAAAAAAAAAAABABABAAAABAAAABAAAAAAA
M	331	0.45		
SD	94	0.36		

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