Chapter 3
Temporal Uncertainty during Overshadowing: A Temporal Difference Account

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ABSTRACT

Standard associative learning theories typically fail to conceptualise the temporal properties of a stimulus, and hence cannot easily make predictions about the effects such properties might have on the magnitude of conditioning phenomena. Despite this, in intuitive terms we might expect that the temporal properties of a stimulus that is paired with some outcome to be important. In particular, there is no previous research addressing the way that fixed or variable duration stimuli can affect overshadowing. In this chapter we report results which show that the degree of overshadowing depends on the distribution form - fixed or variable - of the overshadowing stimulus, and argue that conditioning is weaker under conditions of temporal uncertainty. These results are discussed in terms of models of conditioning and timing. We conclude that the temporal difference model, which has been extensively applied to the reinforcement learning problem in machine learning, accounts for the key findings of our study.

INTRODUCTION

Overshadowing is a procedure in which a target conditioned stimulus (CS1) is conditioned together with a second stimulus (CS2), usually in a simultaneous compound which co-terminates with the delivery of an unconditioned stimulus (US). This training results in attenuated (or *overshadowed*) responding to CS1 when it is subsequently tested alone, compared to the case in which CS1 is con-

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ditioned in isolation. A key variable in determining the degree of overshadowing is the relative salience of the two stimuli: the more salient the overshadowing stimulus relative to the target, the more overshadowing is observed (Mackintosh, 1976). This observation may be interpreted theoretically in terms of learning models such as that proposed by Rescorla and Wagner (1972): the limited amount of associative strength that may be supported by the US must be distributed between the two competing CSs; as speed of acquisition depends on stimulus salience, this distribution is affected by the relative salience of the two stimuli.

However, pairing a CS of fixed duration with a US is a procedure that informs the animal not only *that* the US be delivered, but also *when* it is to be delivered, and there is good evidence to suggest that animals are indeed able to time the delivery of a US (e.g. Kirkpatrick & Church, 2000). This observation makes little contact with standard associative models of conditioning (e.g. Mackintosh, 1975; Pearce & Hall, 1980; Rescorla & Wagner, 1972) which, despite accounting for the magnitude of conditioned responding to a CS, generally fail to provide a comprehensive account of how animals learn about the temporal properties of the CS. More detailed discussion of theories of timing will be postponed until the general discussion; at this point it is sufficient to note that standard associative theories typically fail to conceptualise the temporal properties of a stimulus, and hence cannot easily make predictions about the effects such properties might have on the magnitude of overshadowing. Despite this, in intuitive terms one might expect these temporal aspects to be important. As noted above, the most important determinant of the degree of overshadowing is usually thought to be the ease with which the overshadowing stimulus can acquire associative strength. One can, however, make a parallel argument about a stimulus' temporal properties; given that better predictors of the US acquire associative strength more easily than unreliable predictors, then one might expect a fixed stimulus to be a better overshadowing stimulus than a variable one. This is because, in some sense, a stimulus of fixed duration is a more reliable predictor of US outcome than one of variable duration, as the fixed stimulus gives precise information about the time of US delivery while the variable one does not.

There is no previous research addressing the way in which fixed and variable CSs can produce overshadowing; however, Kohler and Ayres (1979) examined the ability of fixed and variable duration CSs to produce blocking. They conditioned animals to a tone-light compound; for two groups of animals both tone and light were fixed, and one group was pretrained with a fixed light. For another two groups both tone and light were of variable duration and one group was pretrained with a variable light. They found equal blocking in both groups, suggesting that a fixed stimulus was no more able to produce blocking than a variable one. However, this conclusion is complicated by the fact that the treatment of the pretrained stimulus was confounded with the distribution of the to-be-blocked stimulus: the fixed stimulus blocked a fixed target and the variable stimulus a variable target. Moreover, subsequent work has suggested that a fixed CS may after all be a more effective blocking stimulus than a variable (D. Jennings and K. Kirkpatrick, unpublished data). It should be noted, however, that neither of these studies included any groups trained to the target alone. As a consequence, it is impossible to assess what effect the temporal distribution of the stimuli had on their ability to produce an overshadowing effect. This was, therefore, the purpose of the present experiment.

The experiment employed six groups of Lister hooded rats (Harlan UK, Table 1) maintained on a restricted diet at 80% of their free feeding weight. Since we used a houselight as one of the stimuli the boxes were normally not illuminated. All six groups were trained with a light CS that produced diffuse illumination of the conditioning chamber of about 200 lux when operational; three groups (Fc, VF and FF) experienced the light for a fixed