Mackintosh and Associationism

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Abstract

In his own estimation, N.J. Mackintosh's major contribution to psychology was to be found in his books. Foremost among these are the two (1974 and 1983) that dealt with animal learning and conditioning. The central theme of both books, implicit in the first and explicit in the second, was the way in which the phenomena of animal learning could be explained in terms of the notion of association formation (a review of the 1974 work referred to Mackintosh as "the compleat associationist"). In fact his associationism was not "compleat" -- he is widely known for his emphasis on the role played by attentional processes in learning; and he was surprisingly modest in his assessment of the role of associative mechanisms in human learning. Nonetheless, an associative analysis was successfully applied not just to Pavlovian conditioning, but also to instrumental learning, avoidance, discrimination learning, spatial learning, and some aspects of perceptual learning. Although resisted by some, his persuasive writing established the associative account as the default position – that researchers today are still busy trying to prove him wrong is a tribute to the power and persistence of the ideas he developed.

Mackintosh and Associationism

If I have given you delight
By aught that I have done,
Let me lie quiet in that night
Which shall be yours anon:

And for the little, little, span
The dead are born in mind,
Seek not to question other than
The books I leave behind.

(R. Kipling: "The Appeal")

In an interview conducted shortly before his death, Nick Mackintosh was asked about which of his achievements (in psychology) he was most proud. He unhesitatingly identified his books; and although he did not appeal to us to restrict our questioning to these, he would no doubt have welcomed the fact that they continue to be worth our serious consideration (and sometimes, indeed, questioning).

Table 1 lists Mackintosh's authored books and also presents the number of citations of each, as recorded by Google Scholar at the end of 2015. His work on intelligence has been very influential, but, as he would himself allow, this was something of a sideline. His central contribution has been to the psychology of animal learning, and the citation counts for the first three books in the list attest to his importance in this field. In addition we should note that these three are book-ended by two edited works on the topic of learning. They were preceded by *Fundamental Issues in Associative Learning* (1969, edited jointly with W. K. Honig), and followed by *Animal Learning and Cognition* (1994), a volume constituting part of a *Handbook on Perception and Cognition*.[1] Both of these include lengthy essays by Mackintosh as editor. Taken together these works allow us to trace the development of Mackintosh's view of association formation as being a fundamental mechanism of cognition, and of his opinions concerning possible constraints on this analysis.

Discrimination Learning and Attention

Although it appeared a couple of years after *Fundamental Issues*, the book written jointly with Stuart Sutherland, *Mechanisms of Animal Discrimination Learning*, deserves to be considered first. It had its origins in the work that Mackintosh did for his doctorate (Oxford,

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[1] For completeness we should also mention his edited work (Mackintosh, 1995) on Cyril Burt.

1963). During the 1960s, attempts to establish a general theory of learning and behaviour were dominated by Hull's S-R (stimulus-response) reinforcement theory. The generation of psychologists trained at that time may have devoted their energies to finding fault with Hull, but they absorbed the general principle that association formation was a central explanatory concept. One influential figure at Oxford was J.A. Deutsch, who developed an account (e.g., Deutsch, 1964) that dealt with the phenomena considered by Hull, but which emphasized the formation of associations between the representations of stimuli. Another was Sutherland (Mackintosh's doctoral supervisor); he stayed with some form of S-R theory in his account of discrimination learning, but emphasized the role of perceptual or attentional processes in determining the nature of the S, and the role of learning in determining attention. Mackintosh's doctoral work was concerned with testing and developing this theory. It provided early instances of things that were to acquire substantial importance subsequently. At the empirical level there was an early demonstration of the phenomenon later known as "blocking" (Mackintosh, 1965); at the theoretical level it involved adoption of the notion that attention to a cue will be strengthened when the expectation of a particular outcome is confirmed, and will be weakened when it is disconfirmed – that learning depended on the ability of the cue to provide information.

When a full statement of the theory and of its supporting evidence appeared in the 1971 book, some aspects had already been overtaken by events. Mackintosh moved to Dalhousie University in 1967, and in 1968 helped organize the conference held there on which the *Fundamental Issues* volume was based. This conference included a report (by Kamin) of a version of blocking that was to become much more widely known than that of Mackintosh; and there were separate reports by Wagner (on the importance of cue validity) and from Rescorla (on correlational effects in conditioned inhibition) that supported the idea that learning about a cue depended on its informativeness or predictive power. In his final summary chapter Mackintosh sketched out how a theory, like that later proposed as the Rescorla-Wagner (1972) model, could be developed, and might be able to deal with many of the phenomena of interest, without recourse to a concept of attention. But he also identified some phenomena that would be problematic for a theory of this sort. He discussed how an alternative theory, that gave a central role to changes in the properties of the stimulus (i.e.,

an attentional theory), might be developed, and outlined experiments that might be done to test it. Thus, even before the publication of the theory presented in *Mechanism of Animal Discrimination Learning*, Mackintosh was already anticipating the notions that would be expressed in his influential 1975 publication concerned with variation in stimulus associability (Mackintosh, 1975).

Publication of the 1975 theory was associated with a set of experimental reports testing its implications, and Mackintosh continued to study the way in which experience can modify stimulus processing, and hence discrimination, throughout his career. The outcome was a theory (McLaren, Kaye, & Mackintosh, 1989; see also McLaren & Mackintosh, 2000) that dealt with perceptual learning more generally, while retaining the essence of an associative account of conditioning. This last point is critical. Although we may accept that, in order to make the theory workable, it is necessary to specify the stimulus-processing mechanisms involved, it remains the case that the fundamental explanatory process is association formation – attentional and perceptual learning processes are subsidiary forms, adjuncts to the associative machine that some suppose to lie at the heart of cognition. Mackintosh's two most widely cited books were devoted to associative learning.

The Psychology of Animal Learning

For a previous generation, the "bible" on the topic of conditioning and learning had been the book of that title by Hilgard and Marquis (Kimble, 1961). The aim of the original work had been to set out the facts of conditioning so as to allow an assessment of the attempt to use conditioning principles to explain learning generally. It did not set out to summarise and compare rival theories; rather it laid out the facts in a systematic manner, noting their implications for theoretical positions as it went along. Mackintosh's *Psychology of Animal Learning* took the same approach, and rapidly took the place of its predecessor. The sheer amount of experimental work that had been read, sorted, and digested, was impressive in itself. And the clarity of the presentation meant that the outline of the whole of the wood could still be discerned even though individual trees were properly described. The student could rely on this new bible for instruction and guidance on the central issues and research on classical and instrumental conditioning, contrast, reinforcement, generalization, punishment – and so on. For many years this volume provided the starting point (if nothing

more) for anyone wanting to learn about one of these topics (and it thus shaped the thinking of the generation brought up on it).

The book received an extensive review in the pages of the *Journal of the Experimental Analysis of Behavior* (Weisman, 1975), and the title given to this review clearly reveals what the book's central message was perceived to be: "The compleat associationist: A review of NJ Mackintosh's *The Psychology of Animal Learning*". Weisman's review acknowledged that there was a good deal in the book that was not advancing any particular theoretical line, but which consisted of empirical generalizations based on a thorough review of the relevant literature. Among the points picked out by Weisman for special mention are the following:

• that stimulus substitution theory still held its own as an account of the nature of the conditioned response

• that classical CRs are not modified by their consequences

• that instrumental training necessarily involves Pavlovian contingencies and these contribute to (in some cases, completely account for) the behaviour observed

• that learning can occur about the relation between a response and its consequences, especially when performing the response generates salient feedback

• that sensory preconditioning provides evidence that animals can associate motivationally neutral events.

But having noted such points Weisman went on to say that interwoven among this material was a "pervasive associationistic theory of learning". He expanded on this: "Mackintosh means that the neural correlates of events, stimuli, responses, and reinforcers are associated inside animals' heads…Animals learn what leads to what." (p. 386) Thus, he went on:

• in classical conditioning they associate stimuli with reinforcers

• in instrumental learning they associate response with reinforcers

• in punishment they learn to associate responses with aversive reinforcers

• in avoidance they learn to associate responses with the omission of expected reinforcers.

In summary, "animals know about events after having learned correlations between them. And knowing is what cognitive psychology is all about. So the theory … is not just associationist but cognitive as well" (Weisman, 1975, p. 386).

Looking back at these remarks, from the perspective supplied by a distance of 40 years, one is slightly puzzled that it was felt necessary to make them. It is a tribute to the power of Mackintosh's writing that the empirical points he made, and the theoretical line he took, are now so well established that we tend to take them for granted. That they initially provoked this sort of response from reviewers and other readers reminds us that, in his 1974 book, Mackintosh was still working at establishing what came to be the consensus. In fact he was somewhat ahead of his time, on two important issues.

First, the book outlines an account of the associative structures established by various conditioning procedures that is now widely accepted. This is a substantial achievement given the nature of the experimental evidence then available. We now have information from a range of clever experiments (conducted by, e.g., Holland, Rescorla, Dickinson; for a review see Hall, 2002) that confirms the analysis offered by Mackintosh. But, for the most part this experimental work was done in the later 1970s (and later) and was not available to Mackintosh as he wrote.

Second is the emphasis given to the association as a central mechanism in explaining cognitive functioning. From one point of view there was nothing novel about this – indeed it is just what might be expected of a British psychologist brought up in the empiricist tradition of British philosophy. And given that the book is explicitly presented in the introductory chapter as an account of the development of the work pioneered by Pavlov and by Thorndike, their theoretical predispositions can be expected to show through (the latter, after all, was happy to describe himself as a "connectionist"). What is more novel is the almost total reliance on this explanatory mechanism. Reviewers upbraided Mackintosh for this. Weisman, in the review already discussed, complained that Mackintosh's approach led him to neglect areas of study, such as performance on various schedules of reinforcement, that are dear to the heart of those brought up in the atheoretical tradition of the experimental analysis of behavior. (I suspect that Mackintosh's response would have been that there is no need to study such artificial contrivances – but that they would probably succumb to an

associative analysis could one make the effort.) Another distinguished reviewer, J.A. Gray, objected to the failure of Mackintosh to endorse motivational explanations or to address motivational issues (Gray, 1975). Even in the case of avoidance learning (where, according to Gray, the case for a motivational explanation is strongest), Mackintosh insisted on an interpretation in terms not of conditioned motivational states, but of the development of expectations about the consequences of responding.

These are details; the important point about the analysis offered by Mackintosh is as follows. Conditioning studies are seen as a tool that can tell us about the association between particular event representations (sometimes called *nodes*); but the principles revealed by these studies will have relevance to the specification of a "conceptual nervous system" consisting of a huge array of such nodes corresponding to all perceivable stimuli (and possibly, all behavioural outputs). Psychological phenomena are assumed to be determined by the activation of these nodes, and behavioural adaptation by the formation of connections among them, and the propagation of activation around the network. These notions will now seem familiar, being those popularised rather later (e.g., by Rumelhart & McClelland, 1986) under the heading of "connectionism"; but they were anticipated by students of animal learning for whom Mackintosh spoke in *The Psychology of Animal Learning*.

Conditioning and Associative Learning

The theoretical approach that was implicit in *The Psychology of Animal Learning* was fully displayed nine years later with the publication of *Conditioning and Associative Learning.* The focus of the earlier book was its comprehensive review of the literature in various areas of learning; theoretical notions emerged as a consequence. The later book deals with much of the same empirical material, but now the focus is on explanation and mechanism, and the experimental findings discussed are just those that bear directly on theoretical issues. This book, like its predecessor, was the subject of a lengthy review in the *Journal of the Experimental Analysis of Behavior* (Williams, 1987). Much of Williams' review was concerned with a discussion of the distinction between Mackintosh's associative account and the Skinnerian approach likely to be favoured by most readers of that journal. But Williams also did us the service of summarizing in ten fairly brief points, the major conclusions of

Mackintosh's survey. I present a simplified synopsis of these points in Table 2. Again, as most of these points are so seemingly obvious and widely accepted, it is necessary to remind oneself that this was not so in 1983; that it is so now, is because of Mackintosh's work.

As Table 2 shows, the book was concerned almost exclusively with the analysis of classical and instrumental conditioning. The final chapter provided a foray into discrimination learning, but with the stated aim of showing (in the tradition of Spence, 1936) that this form of learning can be explained in terms of principles derived from simple conditioning. Other, possibly more complex, forms of learning were explicitly excluded from consideration (Mackintosh mentions, for example: problem-solving, imprinting, navigation, and performance on operant schedules of reinforcement), largely on the grounds that there was enough to say about conditioning. We can only speculate as to whether or not Mackintosh thought that these too could be explained in associative terms, given time and effort. A clue is provided in the very last paragraph of the book where he writes: "… it should not be forgotten that animals are probably not just machines for associating events" (p. 277). Not much more is said; the only specific case cited is that of spatial learning, about which he writes: "What does seem certain is that the perceptual processing and learning involved [in spatial learning] is somewhat more complex than anything involved in most studies of simple conditioning" (Mackintosh, 1983, p. 264).

Well if that is what he thought in 1983, I suspect that this was just because he had not yet got round to putting his mind to the subject. But he shortly did so; 1985 saw the publication of the first of a series of experimental studies (Diez-Chamizo, Sterio, & Mackintosh, 1985) on the topic of spatial learning, done in collaboration with Victoria Chamizo and colleagues at the University of Barcelona. The central issue was the extent to which spatial learning obeys the standard laws of associative learning, in contrast to the suggestion (as proposed by O'Keefe & Nadel, 1978) that it depends on the animal's ability to form some sort of spatial map or representation of its environment. This first paper manipulated intra-maze and extra-maze cues and demonstrated blocking and overshadowing effects like those seen in standard conditioning procedures. The authors concluded, modestly, that if spatial learning using extra-maze cues depends on the acquisition of some sort of map then the learning involved in this "interacts with other forms

of learning in very much the same way as conditioning to a light interacts with conditioning to a buzzer" (p. 252). As the evidence began to build up over the course of the research programme that followed, modesty gave way to assurance. By 2002, Mackintosh was able to summarise his conclusions in a review paper with the unequivocal title: "Do not ask whether they have a cognitive map, but how they find their way about". How they find their way about turns out to be interestingly complex – it certainly involves much more than a simple turn in response to a choicepoint stimulus, or the acquisition of approach strength by a cue located near the goal – but the mechanisms involved are based on, or at least consistent with, the principles of associative learning.

The successes of associative theory when skillfully applied in the field of spatial learning make one wonder about the other areas (mentioned above) that Mackintosh excluded from consideration. Could he have been equally successful in applying his general associative theory to these, if time (and inclination) had allowed? Sadly we will never know. We do know, however, of one area of psychology that he felt lay outside the scope of associative theory; I discuss this next.

Animal Learning and Human Cognition

The aim of animal learning theory is not to discover new facts about the behaviour of the laboratory rat; rather it is to devise an account of behavior that has general relevance, applying, indeed, to our own species. This is what an earlier generation of psychologists (e.g., Hull, Skinner) claimed to have achieved. In his later writings, Mackintosh gives the impression of being distinctly embarrassed about such claims, and somewhat defensive about the scope of his own achievements. The introductory chapter of his 1983 book refers to the claims of his predecessors as "extravagant" and acknowledges that, with the onset of a more "cognitive" psychology (a term to which we must return), people might be surprised that anyone should be continuing to study conditioning in the laboratory at all. He goes to suggest, however, that such critics could be poorly informed -- that modern learning theory is more complex and interesting, and has more to offer, than they know. This is certainly the tone of the introductory material for his final edited volume on the topic, *Animal Learning and Cognition* (1994), where he seems humbly grateful for the swing of the pendulum that has

allowed a volume on animal learning to appear as part of a *Handbook of Perception and Cognition*.

The position is stated most clearly in review article published a little later and entitled: "Has the wheel turned full circle? Fifty years of learning theory, 1946 - 1996" (Mackintosh, 1997). According to Mackintosh, at the start of this period learning theory occupied a central, even pre-eminent, position in psychology; but it was brought down low, as the wheel of history turned in the direction of cognition. This low point, about 25 years later, showed itself in two main ways. That many psychologists embraced the cognitive revolution had positive effects; there was a broadening of the range of topics studied – Mackintosh mentions categorization, concept learning, analogical reasoning, transitive inference, and several others. But there was a negative side: the risk that "in their haste to climb aboard a cognitive bandwagon, animal psychologists …[might] abandon some hard-won achievements of classical learning theory" (p. 882). And a more serious problem was that psychologists generally, in their enthusiasm for cognitivism, were failing to recognize the real nature and scope of associative theory. Mackintosh's hope was that the wheel would turn again, if critics of learning theory could be more fully informed on these matters. It is worth quoting at some length his summary of his attempt to do this.

> Properly understood…associative learning theory is remarkably powerful. Of course, such a theory must acknowledge that the laws of association are much less simple than those of temporal contiguity between stimulus, response, and reinforcement. It must reject the restrictive assumption of S-R theory … and should assume that a representation of any event, be it an external stimulus or an action, can be associated with the representation of any other event, whether another external stimulus, a reinforcer, the affective reaction elicited by the reinforcer, or an animal's own actions. Equally important … it must allow that the representations of external events may be quite complex. They need not be confined to a faithful copy of an elementary association…they may be representations of combinations or configurations … once we have allowed associative learning theory these new assumptions we have a powerful account capable of explaining …

behavior that many have been happy to label cognitive and to attribute to

processes assumed to lie beyond the scope of any theory of learning.

(Mackintosh, 1997, pp. 883-884).

The material that followed this statement, and put flesh on the bones of its claims, showed

how the extended theory was capable of explaining performance on complex discrimination

and categorization tasks, spatial navigation, and some instances of analogical reasoning. For

these "…appeal to more mysterious cognitive processes is often neither necessary nor

helpful" (p. 890).

At this point the reader might be tending toward the conclusion that "cognition" is not

to be regarded as a set of processes different from those assumed in associative learning

theory, but rather, is simply a label for a set of phenomena that, it turns out, can be explained

by means of the theory. But this is not Mackintosh's view. Having described the successes of

associative theory he goes on immediately to say: "Few psychologists, however, would deny

the importance of a variety of cognitive processes when it comes to explaining our own

behaviour … Associative analyses have an important role to play in any complete

explanation of human behaviour [but] this is certainly not to deny the importance of numerous

cognitive processes or operations that lie outside the scope of an elementary associative

analysis. We do, for example, attempt to solve problems by inducing rules and testing our

hypotheses. When we behave in this sort of rule-governed way, our behaviour is not

amenable to a simple associative analysis" (Mackintosh, 1997, p. 890).

I can well imagine, in fact, that there will be many psychologists willing to dispute this

intuition (see, for example, Skinner's, 1969, discussion of rule-governed and contingency-

shaped behavior in problem-solving). But the assertion relies on more than intuition; sceptics

will need to deal with empirical basis for the claim, which includes observations like the

following. When Mackintosh presented human subjects with discrimination tasks like those

given to his pigeons, they normally showed rather different patterns of performance. They

could be induced to behave like pigeons, however, in certain circumstances; for example,

when the stimuli were too complex for a simple verbal description, and when a very rapid

response was required. What could be more natural then, than to offer a dual-process

account (see also McLaren et al., 2014) – a cognitive ruled-based system that operates

under normal circumstances, and the associative system (held in common with other species) that comes into action when the other system is unable to function. Mackintosh went on to propose that the associative system was likely to be involved in a variety of implicit learning procedures; also that it provided a successful account of the performance shown when people are asked to judge contingencies between events (e.g., Dickinson & Burke, 1996). These are, no doubt, worthwhile achievements. But this reader, at least, is left with the feeling that this is something of a come-down for learning theory – to be assigned merely to a subordinate role, useful for dealing with events when you have no time to think.

Envoi

But we need not end on such a gloomy note. Human cognition may indeed involve processes other than those to be explained in terms of direct associations between the representations of events—but there is more to associationism than this. And it is all very well to describe these other processes as involving the use of rules or the manipulation of propositions, but these are indeed just descriptions rather than specifications of the mechanisms involved. The use of a rule or the construction of a hypothesis, are forms of behavioural adaption that are themselves in need of explanation. In one of his last contributions to the field, Mackintosh (in company with his collaborators; McLaren et al., 2014) made a start at dealing with this issue. I do not think he would have wanted to claim that the matter was settled, but we can record that the best attempt at explaining the nature of rule-based symbolic processing turned out to be in terms of a connectionist network; that is, in terms of a system using the associative principles that were central to his life's work in psychology.

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Table 1

Mackintosh's authored books

Title	Date	Citations
Psychology of Animal Learning	1974	2338
Conditioning and Associative Learning	1983	1100
Mechanisms of Animal Discrimination Learning	1971	893
IQ and Human Intelligence	1998	625

Note: Citations are from Google Scholar, December 2015. In addition, Mackintosh edited

three other books (discussed in the text), and a second edition of *IQ and Human*

Intelligence was published in 2011. *Mechanisms of Animal Discrimination Learning*

was co-authored with N.S. Sutherland.

Table 2

Williams' summary of *Conditioning and Associative Learning*

(a) Classical and operant conditioning are separate processes, involving different associative units; different rules of performance govern these conditioning processes.

(b) Stimulus substitution theory provides an adequate account of the nature of the conditioned response.

(c) The unit of learning in instrumental learning procedures is the response-reinforcer association; the function of the discriminative stimulus is to serve as a conditional cue informing the animal of the response-reinforcer relation.

(d) Punishment is the symmetric opposite of positive reinforcement -- the animal learns the association between the response and the consequent aversive event.

(e) The effects of reinforcers involve two separate types of associations: between the response and the general hedonic effects of the consequent event, and between the response and the sensory properties of the particular reinforcer.

(f) Avoidance learning requires an analysis in terms of the events immediately consequent upon the avoidance response. Two-factor theory is unnecessary, because response-produced cues will become conditioned inhibitors with respect to aversive stimulation and thus assume positive value in their own right.

(g) Contingency effects can be derived from the more molecular principles that excitatory conditioning occurs whenever an "unpredicted" reinforcer occurs, and that inhibitory conditioning occurs whenever a "predicted" reinforcer fails to occur.

(h) The determinants of the strength of an association include not only the degree of temporal proximity between the elements of the association but other factors, including relative predictiveness, spatial contiguity, similarity, and "relevance."

(i) The degree to which a stimulus or response enters into an association depends upon past experience, as previous exposures of the stimulus or response in conditions in which nothing of consequence is predicted by those elements will cause them to lose "associability".

(j) Discrimination learning is best analyzed in terms of the more elementary processes of conditioning and extinction, as in the tradition of Spence.

Note: This is a simplified synopsis of the central points made by Williams (1987).