Cue Competition in Human Incidental Learning

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Abstract

There is a question as to whether cue competition effects can be observed in incidental learning paradigms in humans. Some authors have reported that cue competition is not observed, suggesting that previous demonstrations of cue competition have relied on explicit awareness of the task in hand. This would in turn imply that these effects are more likely to be the product of cognitive inference than associative learning. We addressed this question by using two paradigms previously shown to produce associative learning under incidental conditions. One was a standard SRT task in which the preceding two trials of a run of three predicted the third 2/3 of the time, and the other was based on another predictive cue, a colored square, which could also stochastically predict the next response required. Both tasks were run under incidental conditions, and we have demonstrated in other studies that both cues would support learning in these circumstances in the absence of any verbalisable knowledge of the rules involved. The question was to what extent would these two cues compete if run concurrently, as assayed by their ability to make the next response faster and more accurate than controls? We assessed this by comparing a dual cue group to a color only control and a sequence only control. Our results showed that all three groups learned, but that during a test phase where each cue could be assessed independently, the dual group showed a marked decline in performance relative to the color control, and very similar performance to the sequence control. We interpret this as evidence for overshadowing occurring between the two predictive cues in the dual group, such that when combined their performance would be equivalent or superior to either control, but when assessed independently, the color cue actually has a weaker association to the outcome than the equivalent cue in the control group. We conclude that the sequence cues overshadowed the color cues in this task, and discuss possible theoretical accounts of this phenomenon.

Keywords: Cue competition, Overshadowing, Associative, Incidental

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Cue Competition in Human Incidental Learning

We start by considering the phenomenon of overshadowing, as this is a paradigmatic example of cue competition, a domain that also encompasses blocking (Kamin, 1968). The result here is that, if two quite distinct, equally salient cues, A and B, are trained in compound to predict a US, then responding to either A or B is less than would be seen if that cue had been trained in isolation. If one cue, say A, is more salient than B, then it tends to dominate learning, and relatively little accrues to B (see Mackintosh, 1976, for just such an experiment). This result is easily explained by associative theories. According to the Rescorla-Wagner model, the two cues, A and B, share the associative strength to the outcome between them in proportion to their relative salience. Pearce's (1987) configural theory arrives at the same result by a different route, arguing that learning about AB generalises only imperfectly to A or B, again to an extent determined by the relative salience of the cues involved. Associative theories, then, provide good explanations of cue competition phenomena.

Equally, however, there is no doubt that an approach based on cognitive inference can explain overshadowing, by taking the view that the subjects in the experiment are using a heuristic of the type "if there are two cues predicting the outcome, then credit for this prediction must be shared between them according to their salience". For example, this heuristic can be used to explain the results of allergy prediction paradigms such as in Le Pelley and McLaren (2001), where a combination of two foods, A and B, predict an allergic reaction in a hypothetical patient, "Mr. X". The result is that the ratings for A and B are less than that for control cues trained on their own to predict the same outcome.

If the results of such experiments are equally well explained by either associative or inferential accounts, how will it be possible to decide between them? In humans, one way may be to use procedures that make it unlikely that participants will be able to employ cognitive inference – which we assume relies on working memory which has a limited capacity. Le Pelley, Oakeshott and McLaren (2005) argued that using many different trials, presented in a random order, each employing some of a large number of stimuli with different relationships to the available outcomes should make it hard for participants to keep explicit track of the contingent relationships in the experiment. Le Pelley and McLaren (2001) were also at pains to use these conditions (high memory load due to using many cues and trial by trial presentation) for similar reasons, so it seems plausible to argue that the cue competition effects they observed were probably associative in origin, but we cannot be certain that this was the case. In many other cases, where few cues are used and memory load is low, the rating given may well owe more to cognitive inference than associative learning.

One particular version of this inferential heuristic for overshadowing requires that the subject, whether animal or human, knows which cues predict which outcomes, and then uses this information to generate behaviour. We can characterise this account of overshadowing as reliant on explicit memory as well as learning. This explanation of overshadowing takes on particular relevance when we consider the claim that humans do not show cue competition effects (Jimenez and Vazquez, 2011) under incidental conditions. If this is because people do not have access to the necessary explicit cue-outcome information required for cognitive inference to be brought to bear and hence produce overshadowing, then this would be good evidence that humans learn propositionally, and when the relevant information is unavailable, cue competition effects do not occur. It would also suggest that reinforcement learning in humans is driven by different mechanisms to those in other animals. If, on the other hand, cue competition effects could be demonstrated under incidental conditions in humans in the absence of explicit cognitive inference, then this would be entirely consistent with an associative account of learning under these conditions, and would suggest strong parallels between human and infra-human learning in these circumstances.

Design issues

We have already indicated that demonstrations of overshadowing using the allergy prediction paradigm, whilst robust, are susceptible to the complaint that they may be propositionally driven rather than associatively mediated. A second issue is that the stimuli that serve as the CSs in these experiments may be too similar in kind, in that they are both foods. The analogy would be to an animal experiment in which the overshadowing was demonstrated to two tones of different pitch, rather than a tone and a light. The former might give rise to concerns that the two tones when played together interacted in some way so as to change their stimulus quality, and that this interaction was lost when presented individually, so that the reduction in rating that occurred on test could be explained by some change in the perceived stimulus. No such

process would apply when the stimuli were trained alone. It would clearly be better if the two CSs were different in kind so that this type of potential confound could be avoided. Our two classes of cue were chosen to have quite distinct characteristics to avoid this problem. We employed a basic SRT paradigm similar to that of Willingham, Nissen and Bullemer (1989), in which there were two circles that defined two stimulus locations, left and right. At the start of a trial, the circles are outlines, then one of them fills, and the corresponding key has to be pressed. Unknown to the participants, in those groups that were given sequential information, there was a 2/3 chance of a trial being predicted by the two preceding trials. The rule was that if the two preceding trials were both the same, then that trial was likely to be an X, whereas if they were different, it was likely to be a Y, with the response assignments for X and Y counterbalanced across participants. Thus, the first type of cue was provided by the sequence of locations that occurred / responses required. The second cue type was provided by a colored square that flashed up before the circle filled in, presented at fixation between the two circles. Participants for whom color information was relevant had a 3/4 chance that the color would predict the response location on half the trials. On the other half of trials different colors were used that were not predictive, and these could be used as color control trials. We settled on these parameters for the tasks on the basis of extensive piloting and prior work, to ensure that both the sequential information and the color information were capable of supporting learning under incidental conditions, but without participants inducing the rule relating either type of cue to the required response (see Jones and McLaren, 2009 for more on the sequences, and Yeates, Jones, Wills, Aitken and McLaren, 2012, 2013 for details on the colour task). Table 1 gives the stimulus construction for each group.

GROUP	S1	S2	S3	S4	S5	S6	S7	S8
COLOR	XXX 431	XXY 242	XYX 321	XYY 332	YXX 141	YXY 412	YYX 431	YYY 342
SEQUENCE	XXX 431	XXX 242	XYY 321	XYY 332	YXY 141	YXY 412	YYX 431	YYX 342
DUAL	XXX 431	XXX 241	XYY 322	XYY 332	YXY 142	YXY 412	YYX 431	YYX 341

Table 1: This shows the construction of the stimulus sequences and contingencies for the three groups (N=30 for each group) in an idealised form to convey the relationship between the groups. Sequences and mappings were randomised / counterbalanced where appropriate. The letters (X, Y) stand for left/right responses, and the numbers (1, 2, 3, 4) for colors. Stimuli shown in red are those changed with respect to Group Color. In Group Color colors 1 and 2 are predictive, and 3 and 4 act as controls. All 8 sequence triplets are shown that were used to construct the pseudorandom trial order. In Group Sequence no color is predictive, but only 4 sequence triplets are used so that e.g., XX is typically followed by X. In Group Dual colors 1 and 2 are once again predictive, and so are the sequences. There were 16 blocks of training and 2 blocks of test, with each block containing 96 trials.

Another point worth raising is that in all the experiments (that we are aware of) that have studied overshadowing in humans that come close to meeting our first two conditions, i.e. incidental learning with dissimilar cue types, the comparison has been between CSs trained in compound and tested individually, and a group or groups trained with the individual CSs and then tested. The problem with this procedure is that one group experiences a major change from training to test (the compound group) whereas the other does not. This, on its own, may be enough to depress responding in the compound group if they come to believe that circumstances have changed and deliberately and strategically alter their responses as a consequence (something that seems intuitively less likely to be the case in a rat or a pigeon). Note that this is not the same as a generalization decrement account of overshadowing that would, for example, follow from Pearce's (1987) configural model. It is rather an appeal to a strategic decision based on changing circumstances during the course of the experiment, and we avoided this in our design by making sure that the transition from training to test was unsignalled and unlikely to be noticeable. Table 1 shows how Group Dual had both sequence and color information programmed in, Group Color had the same type of color information as Group Dual, and Group Sequence had the same type of sequence information as Group Dual. Group Sequence were still shown a colored square just before the response location was indicated, but the color bore no relation to that location; equally Group Color experienced sequences of trials in just the

same way as Group Dual, but these were not predictive. The point is that all groups experienced a fast-paced sequence of trials (mean RT = 300 msec, and mean errors per block = 4) cued by a colored square during both training and test, so there should be no obvious difference in their subjective experience, and no obvious difference between training (when the contingencies were as shown in Table 1) and test (when all contingencies were 50:50, and sequence and color information were uncorrelated).
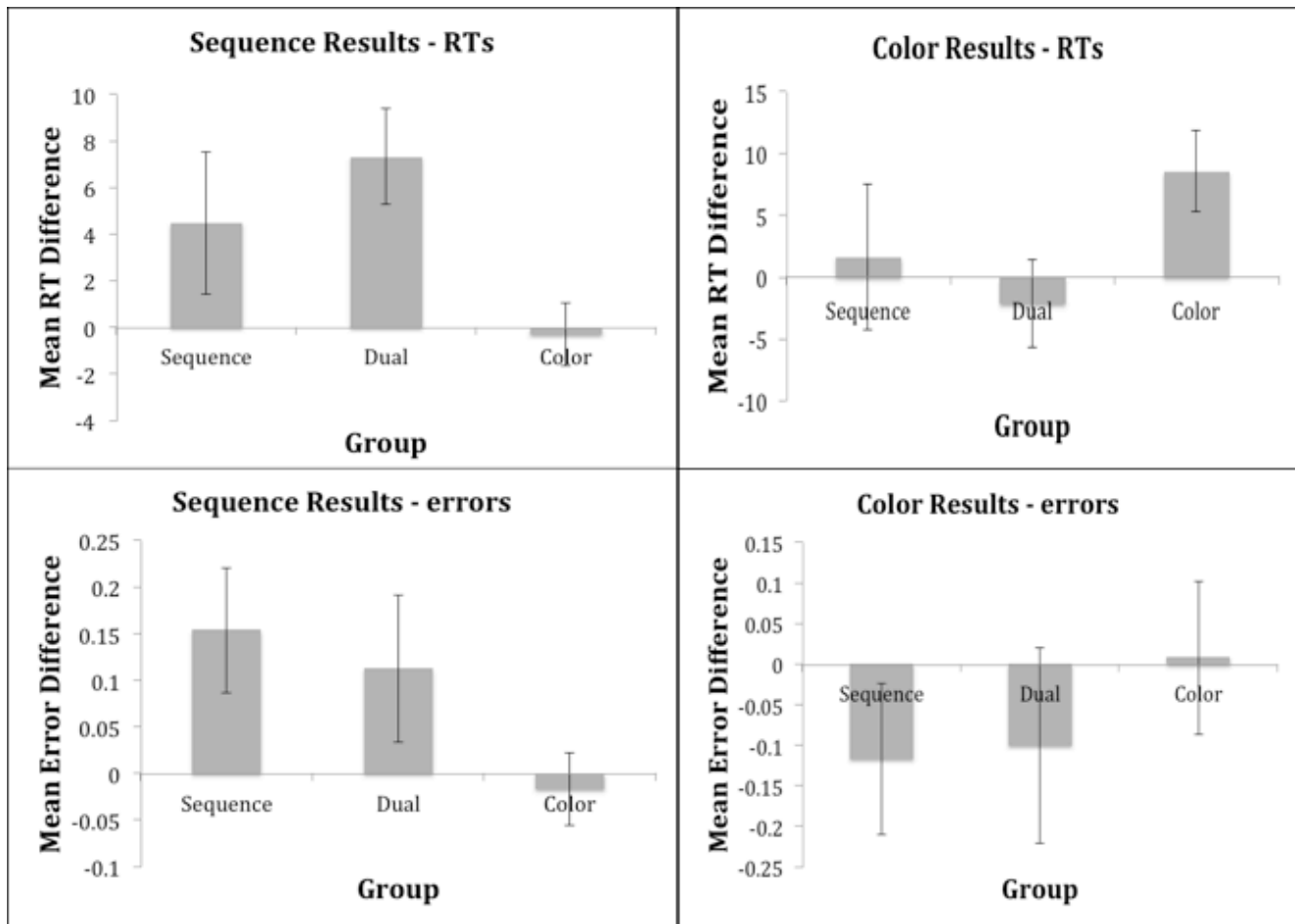
Results

Figure 1: The top panels display the mean differences in RT (msec) and their standard error analysed by sequence (left panel: untrained sequences–trained sequences), and by color (right panel: untrained colors–trained colors). The corresponding mean error differences and their standard errors are shown underneath.

Figure 1 shows the test results for sequence and color learning. The data shown in Figure 1 are the mean difference between trained and untrained sequences (left panels) or colors (right panels) in RTs (top panels) and errors (bottom panels) for each of the three groups. Higher scores indicate more learning (chance is zero), and it is clear that both the Sequence and Dual groups showed good evidence of sequence learning (left panels) as measured by RTs and errors, whereas there was little evidence of learning in the Color group on this measure. Given that the test phase was, in effect, an extinction treatment, the evidence for sustained performance on the basis of what had been learned during training in Group Sequence and Group Dual is noteworthy and implies strong learning of the sequence information available during training.

The right hand panels show the difference scores obtained by comparing performance for the predictive colors with the control colors for RTs and errors on test. Group Dual showed no evidence of learning about the colors on either the RT or the error measure (unsurprisingly, the same was true for Group Sequence). Although Group Color also showed little or no evidence of learning on the error measure, their RT performance showed a significant effect, and was significantly better than that of the other two groups.

Conclusions

It would appear, then, that the Dual group learned about the sequences, but did not learn the color

information available to them, even though Group Color shows that this was eminently possible. This is what would be expected if the sequence cues had overshadowed the color cues in the Dual group (but not vice-versa). Thus, it is possible to demonstrate cue competition effects in humans trained under incidental conditions, and we believe this to be the first such demonstration. Were the participants in this experiment aware of the sequence or color rules? Previous experiments and pilot work suggest that this should not be the case, and post-experiment interviews established that participants were unable to give any accurate information about the sequences, or say which colors were predictive. Crucially, there was no difference between Dual and Color groups in terms of their ability to guess which colors were predictive (44% and 45% respectively), and both values are numerically below chance (50%). Equally, there was no reliable difference in the proportion asserting that the sequences were random (using a conservative criterion in scoring this) in any of the Color, Dual or Sequence groups (50%, 57% and 70%), and the trend favoured the Sequence group as thinking that their sequences were random. Given these results, we can now reject the argument that cue competition in humans is only observed under intentional learning conditions, and its corollary that this is because it relies on explicit cognitive inference to manifest.

How might we explain this effect? As mentioned earlier, there are two standard accounts of overshadowing available, one based on competition for associative strength and exemplified by the Rescorla-Wagner (1972) model, the other based on the idea of generalization decrement with Pearce's (1987) configural model as its flag bearer. Neither are capable of learning the sequential information presented in this experiment, but error-correcting recursive networks such as the SRN (Elman, 1990) and its variants the RASRN (Yeates, Jones, Wills, McLaren and McLaren, 2013) and the APECS SRN (Jones, Le Pelley and McLaren, 2002; and see McLaren, Forrest and McLaren, 2012)) can, and contain one or both mechanisms for overshadowing. Thus, they are able to predict the results obtained here. We are also in a position to say that cue competition experiments in humans under incidental conditions produce the same type of result as that observed in other animals, which is consistent with there being some common basic mechanism for associative learning.

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