STIMULUS OVERSELECTIVITY AND EFFECT OF REWARD HISTORY

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Abstract

Previous research suggests that stimulus overselectivity – exclusive stimulus control by one or only a few elements of a compound stimulus – occurs because elements of higher salience overshadow elements of lower salience. No research, however, has evaluated why some elements are more salient than others in the absence of a differential on any obvious dimension. Two experiments ran procedures standard in inducing an overselectivity effect. Participants discriminated between two compound stimuli, and then selected between elements of both stimuli in a test phase. However, a preliminary procedure associated differential rewards with different colours, in order to determine whether an element containing colours previously associated with higher magnitudes of reward would be overselected when it was presented as part of a training stimulus. Later, the element expected to be most overselected was put in extinction; any emergence for other elements in a subsequent test phase would indicate that overselectivity for an element would be attributable to reward enhancing the salience of the element rather than enhancing attention towards it. Contrary to predictions, there was no effect of reward history; different elements were overselected by different participants irrespective of the reward previously associated with the colour of each. This meant that relatively underselected elements were put into extinction during that phase. In most instances, emergence was observed for the element put in extinction. Furthermore, emergence for elements was often not accompanied by decreases in selectivity of other elements. These findings suggest that the emergence seen in previous studies may be attributable to an artefact of their procedures rather than evidence of an overshadowing account.
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Table of Contents

Abstract.......................................................................................................................................ii

Acknowledgements................................................................................................................iii

Table of Contents......................................................................................................................iv

List of Tables.................................................................................................................................vi

List of Figures.................................................................................................................................vi

Literature Review...........................................................................................................................1

Experiment 1......................................................................................................................................17

Method............................................................................................................................................17

Participants.....................................................................................................................................17

Materials.........................................................................................................................................17

Procedure.......................................................................................................................................18

Phase 1 – Visual Search Phase.......................................................................................................18

Phase 2 – Training Phase...............................................................................................................20

Phase 3 – Test Phase One...............................................................................................................22

Phase 4 – Extinction Phase............................................................................................................24

Phase 5 – Test Phase Two..............................................................................................................26

Results...........................................................................................................................................26

Phase 1 – Visual Search Phase.......................................................................................................26

Phase 2 – Training Phase...............................................................................................................26

Phase 3 – Test Phase One...............................................................................................................26
General Discussion…………………………………………………………………………71

References…………………………………………………………………………………..77

Appendix A: Participant Information Sheet………………………………………………80

Appendix B: Consent Form………………………………………………………………..82

List of Tables

Table 1. Proportion of trials in which each element of Stimulus A was selected for the nine participants………………………………………………………………………………28

List of Figures

Figure 1. An example of the stimulus and elements displayed for a participant on a Phase 1 trial…………………………………………………………………………………………20

Figure 2. An example of the compound training stimuli displayed for a participant on a Phase 2 trial……………………………………………………………………………………22

Figure 3. An example of two elements that were displayed for a participant on a Phase 3 trial………………………………………………………………………………………23

Figure 4. An example of the elements displayed for a participant on a Phase 4 trial……….25

Figure 5. Mean proportion of trials in which each element of Stimulus A was selected in Phase 3 in order of the magnitude of reward previously associated with the colour of each element………………………………………………………………………………..27
Figure 6. Proportions of trials in which each element of Stimulus A was selected in Phase 3, from the most to the least often selected element, for the four participants that demonstrated overselectivity in Phase 3.

Figure 7. Proportion of trials in which each element of Stimulus A was selected in Phase 3 in order of the magnitude of reward previously associated with the colour of each element, for the four participants that demonstrated overselectivity in Phase 3.

Figure 8. Proportion of trials in which the same elements of Stimulus A was selected in Phases 3 and 5, in order of the magnitude of reward previously associated with the colour of each element, for the four participants that demonstrated overselectivity in Phase 3.

Figure 9. An example of the types of stimuli presented to a participant on a Phase 1 trial.

Figure 10. The 4x4 grid that was displayed with the objects that participants were required to remember.

Figure 11. An example of the compound stimuli presented to a participant on a Phase 2 trial.

Figure 12. An example of two elements displayed on a Phase 3 trial for a participant.

Figure 13. An example of the elements displayed on a Phase 4 trial for a participant.

Figure 14. Mean proportion of trials in which each element of Stimulus A was selected in Phase 3, in order of the magnitude of reward previously associated with the colour of each element.

Figure 15. Mean proportion of trials in which each element of Stimulus A was selected in Phase 3, in order of the magnitude of reward previously associated with each element, for the 15 participants that demonstrated overselectivity in Phase 3.
Figure 16. The proportion of trials in which the same elements were selected in Phases 3 and 5, in order of the magnitude of reward previously associated with the colour of each element, for the 15 participants that demonstrated overselectivity in Phase 3.

Figure 17. Mean proportion of trials in which the same elements were selected in Phase 3 and Phase 5, in order of the magnitude of reward previously associated with the colour of each element, for the individuals that had their most (top panel), second most (middle panel) or third most (bottom panel) selected element put in extinction.
Operant responses occur at high rates because they produce particular maintaining reinforcing consequences. These maintaining consequences occur under specific stimulus conditions that signal the availability of reinforcement, contingent on the response. For instance, a rat’s lever press may be reinforced by a food pellet but only in the presence of a particular tone. When an organism only produces a particular response under stimulus conditions that signal the availability of reinforcement, and does not produce the same response (or responds at a lower rate) when those same stimulus conditions are not present, that response is said to be under stimulus control.

Stimulus control can be complex, because stimuli that signal the availability of reinforcement and control responses are often multifaceted – comprised of multiple dimensions or elements (e.g., a red square is comprised of the colour dimension of “red” and the shape dimension of “square”; a bird contains multiple features such as wings, a tail, a beak). In addition, all or some dimensions of this complex stimulus might be important in terms of detecting whether reinforcement will be contingent on the response. A child’s ability to correctly discriminate between multiple different animals, for instance, is dependent on the child being able to identify animals on the basis of more than one of their elements. While two animals could be discriminated on the basis of whether each contain a particular element (e.g. discrimination between a cat and duck on the basis of leg number is possible), discrimination would not be possible between two animals if the sole element used to identify each of them is an element that both animals share (e.g., discrimination between a cat and dog is impossible on the basis of their number of legs). All stimuli in the environment that signal different contingencies have unique values upon particular dimensions that can be used to discriminate them from other stimuli. Thus, the greater the number of elements of a stimulus that an individual can come under the control of, the greater likelihood a response will be emitted in the right context, and hence reinforced.
While it is ideal to demonstrate stimulus control of all elements of a complex stimulus, the behaviour of organisms more often than not comes under much larger – if not exclusive – control by certain elements of a complex stimulus compared to others. This finding, coined the overselectivity effect, can be seen in transfer tests – first demonstrated by Reynolds (1961). In his study, two birds were presented with a Variable Interval (VI) 180s Extinction (EXT) multiple schedule of reinforcement, in which two simple schedules were presented successively, each associated with a particular stimulus. A red key superimposed with a white triangle signalled the VI schedule, while a green key superimposed with a white square signalled the EXT schedule. Birds learned to respond at a higher rate to the red key that contained a triangle than they did to the green key that contained the square, showing that they discriminated between the two stimuli. However, because the two keys differed on the dimensions of colour and shape, it was possible for birds to discriminate between the two keys on the basis of one dimension alone. A subsequent test condition, in which each element of each stimulus (red, green, white triangle, and white circle) was presented alone in extinction, demonstrated that this occurred; birds responded at a differentially high rate to only one element of the complex stimulus associated with the VI schedule. One bird responded at a high rate to the colour red and very low rates for the other three elements, and the other bird responded at a high rate for the white triangle and very low rates to the other elements. This finding suggests that, even when no extra reinforcement is provided for doing so, the behaviour of organisms tends to be overselective, coming under greater, or exclusive, control of one element when they are exposed to a complex antecedent stimulus.

The overselectivity effect is not exclusive to nonhumans. It can be induced in individuals who have learning disabilities with relative ease. Lovaas, Schreibman, Koegel and Rehm (1971) were the first to demonstrate such an effect. They ran a similar procedure to Reynolds’ (1961) with three groups of children: those with autism, those with mental
retardation, and those without learning disabilities. The participants were reinforced for emitting a bar-pressing response in the presence of three stimuli of differing sensory modality (a floodlight, white noise, and pressure applied by a cuff on the participant’s ankle) that were presented simultaneously every 20s. A test phase followed, where the participants were presented with each stimulus separately and sequentially, but at the same rate that they had been presented in the training condition. While participants without learning difficulties demonstrated equally high levels of control for all three stimuli, children with autism and mental retardation responded on more occasions for only one and two of the stimuli, respectively; that is, these latter two groups of children demonstrated overselectivity for certain elements.

The overselectivity effect can be induced in individuals with autism when the complex stimuli consist of as few as two elements. In a variation of their first procedure, Lovaas and Schreibman (1971) arranged similar conditions to that of Lovaas et al. (1971), but they presented a compound stimulus comprised of two, rather than three, elements (white noise and a floodlight) to children with autism and children without autism. On training trials, children were reinforced for emitting a bar-pressing response in the presence of this compound stimulus. Test trials punctuated these training trials, where only one element would be presented. None of the children without autism emitted more responses when one element was presented compared to the other, but seven of the nine participants who had autism did; some participants emitted more responses in the presence of the floodlight, and some emitted more responses in the presence of the noise.

While the overselectivity effect can be induced in those with autism with relative ease, adjustments to the standard procedure are typically required to induce the effect in individuals from nonclinical populations. Reed and Gibson (2005; Experiment 2A), for instance, ran a similar procedure as Lovaas and Schreibman (1971) with a group of
nonclinical participants. The participants were required to select one of two two-element compound stimuli in a training phase (e.g., “AB” rather than “CD”) and received a reward contingent on the selection of the correct compound stimulus (participants were told “No” contingent on an incorrect response). In a test phase, training trials were interspersed with test trials where participants were presented with two elements: one from the reinforced training stimulus and one from the nonreinforced training stimulus (e.g., “B” and “C” might have been presented on one trial, “A” and “C” on the next, etc.). For test trials, no reinforcement or feedback was provided for any response. No overselectivity effect was found for this group; that is, no significant differences were found between the percentages of trials in which the participants selected each element of the reinforced training stimulus. However, a second group of participants underwent the same procedure whilst simultaneously engaging in a distractor task for the duration of the experiment in an effort to increase their memory load (participants were required to remember the configuration of four objects in a 4x4 grid). Unlike the non-distractor task group, a significant difference was found between the percentage of trials in which one element from the reinforced training stimulus was selected and the percentage of trials in which the other element was selected. In other words, when a distractor task was presented simultaneously in the procedure, participants showed overselectivity for one element.

Other adjustments can be made to induce an overselectivity effect in individuals who don’t present with autism. Reed and Gibson (2005; Experiment 1) required one group of participants to discriminate between two pairs of stimuli in a training phase rather than one (e.g., “AB” and “CD” may have been presented on one training trial, “EF” and “GH” on the next, etc.), and then presented them with elements from either the first or second pair of stimuli on test trials (e.g., “D” and “B” might be presented on one test trial, followed by “F” and “G”, then “H” and “E” on the next, etc.). Another group was given the standard
procedure with one pair of stimuli akin to the control group in Reed and Gibson’s (2005; Experiment 2A) study. The group that was required to make discriminations between one pair of stimuli showed no evidence of overselectivity (they selected both elements from the correct training stimulus at equal percentages of trials in which they were presented), but the group that was required to make discriminations between two pairs of stimuli in the training phase did exhibit overselectivity; that is, the group selected one element from a correct training stimulus on a significantly higher percentage of trials than the other element, for both correct training stimuli.

Emphasis has been placed on the special conditions required to induce the overselectivity effect in those without autism relative to those with autism (Reed & Gibson, 2005). The relative ease with which those with autism display the effect relative to those without is often used as evidence of the deficit that those with autism have. However, the difference in conditions required to induce the effect between these populations is actually not that large because a distractor task is not necessary to induce the effect in subclinical individuals if compound stimuli are comprised of three elements rather than two (Broomfield, McHugh, & Reed, 2008).

Given such information, an important question is: What is the mechanism that produces this effect, and is such a mechanism consistent with the finding that the effect is more easily induced in those with autism relative to those without it? Because a simultaneous distractor task, a larger number of elements per stimulus, or a larger number of stimuli in training phases is needed to induce the effect in those without autism, one might contend that the effect is attributable to overloading working memory capacity. This hypothesis is supported by evidence that shows that overselectivity is exhibited to a larger degree when the compound stimulus that controls a response is comprised of a larger number of elements (Reed, Petrina & McHugh, 2011). Control by a larger number of elements would be more
taxing and require greater use of cognitive resources relative to when fewer elements are presented, consistent with a working memory account of the effect. Such an account of the effect might also explain why in certain studies (e.g., Broomfield, McHugh & Reed, 2010) a substantial proportion of participants do not display the overselectivity effect despite it being demonstrated when group data is collated. Because some individuals would be expected to have a greater working memory capacity than others, not all would display an overselectivity effect, even when more cognitively demanding tasks are arranged.

A working memory account of the effect, however, necessitates that those with autism have lower working memory capacity relative to their nonclinical counterparts, given that the effect is more readily induced in the former population. However, evidence (e.g., Ozonoff & Strayer, 2001) suggests no difference in working memory function in those with autism relative to those without it. Furthermore, it is questionable whether the use of working memory would be required to perform the tasks in some studies, given that some of these tasks would not prime participants into actively rehearsing and encoding information about compound stimuli. In each of Reed and Gibson’s (2005) experiments, participants were not warned of the subsequent test phase. For this reason, it would be unlikely that participants rehearsed the compound stimuli when they were presented with them in the training phase; all that was required of them was to select one of the stimuli. Thus, a working memory account would not be able to explain the discrepancy in findings where some participants showed overselectivity when also presented with a distractor task and other participants did not show overselectivity without a distractor task. This is because the same amount of working memory (i.e., none) would be used for remembering elements of a stimuli regardless of whether a distractor task was also present.

Hypotheses other than a working memory account may provide better explanations as to why the effect is more readily induced in those with autism relative to those without it, as
well as being consistent with all other findings. While it is true that a larger array of elements would provide a more taxing load on memory systems, it would also mean that attention would have to be divided to a greater extent relative to when a smaller number of elements are presented. If attention was allocated to some elements more than others, then these elements would be overselected as a result. Lovaas and Schriebman (1971) and others have attempted to explain the overselectivity effect through this attentional account. This account might be more consistent with the findings that show discrepancies in the ease with which the effect can be induced in those with autism relative to those without it, given that individuals with autism tend to fixate on fewer aspects of an object or scene relative to nonclinical controls (Boraston & Blakemore, 2007). Dube et al. (2010) incorporated eye-tracking of participants with and without autism as they performed a matching-to-sample (MTS) or delayed-matching-to-sample (DMTS) task, respectively. For a series of trials, participants were presented with two sample elements, and then (immediately or after 2s) the elements was removed and replaced with three elements, only one of which had been one of the two sample elements just shown. None of the participants without autism selected one sample element more accurately, whereas half of the participants with autism did. Furthermore, the participants with autism that displayed overselectivity for one sample element tended to only fixate on that element when it was presented as one of the two samples. This indicates that one sample element was underselected because less attention was being allocated towards it. The same study provides further evidence that the overselectivity effect can be explained through an attentional account; reinforcing observing responses to the previously underselected element alleviated overselectivity for some participants. Other evidence from eye-tracking done on individuals without autism demonstrates that participants fixate more frequently and for longer periods on elements of compound stimuli that are later overselected (Perez, Endeman, Pessoa, & Tomanari, 2015).
An attentional account is also consistent with research that has shown that an overselectivity effect can be induced more readily in individuals without autism if they are simultaneously provided with a distractor task. Because some attention would be allocated towards this alternative task, less attention would be available to allocate to all elements of a compound stimulus. Therefore, less effort would be used to make the appropriate discrimination (i.e., attending to only one element of a correct compound stimulus) in order to free up attention for a distractor task. Thus, because attention would be disproportionately allocated between the elements of the compound stimulus, more overselectivity would be predicted as a result.

There are problems, however, with an attentional account of the overselectivity effect. When eye-tracking of participants was measured in response to the presentation of a complex stimuli, Perez et al. (2015) found that control by elements was disproportionate to the amount of fixations directed towards those elements. A large degree of control was still found for elements that had no or few fixations directed towards them. This is inconsistent with an attentional account because the amount and duration of fixations towards an element should be correlated with that element’s degree of control. An attentional account would require that participants were also directing covert attention (attention to a stimulus when eyes are fixated elsewhere) towards these other elements. Given that attention in such studies is typically measured by the quantity and duration of eye fixations towards an element, however, this would be impossible to determine. A problem with using a mentalistic, hypothetical construct like attention to provide the basis for the overselectivity effect is that it can only be measured through indirect means, such as eye fixations, and such fixations may not correlate with attention. Dube et al. (2010) provided further evidence against an attentional account. While they were able to find alleviation of overselectivity when observing responses to previously underselected elements were reinforced, this was not true of all participants.
Perhaps the strongest evidence against an attentional account is provided by research showing emergence; that is, behaviour later coming under greater control of elements that were previously underselected. Broomfield et al. (2008; Experiment 1), for instance, in a MTS procedure, presented participants on each trial with a compound stimulus comprised of three elements. After 5s, this stimulus was replaced by four elements. Two of these elements were stimulus elements shown just prior. Participants had to choose one of the elements that had been shown as part of the stimulus. After a series of trials, an extinction phase occurred. In each trial, the element that had been most overselected was presented in conjunction with one of four novel elements, and selection of the previously overselected element was put in extinction while selection of the novel element was reinforced. When a second MTS phase was presented, participants selected the previously underselected elements at a much higher percentage of trials in which it was presented relative to the first MTS phase; in fact, the previously underselected element was selected higher than the previously overselected element, which showed lower selectivity relative to the first MTS trials. This effect is not exclusive to individuals without autism; those with higher-functioning autism appear to demonstrate it as well (Reed, Broomfield, McHugh, McCausland, & Leader, 2008). If certain elements were previously underselected because less attention was directed towards them, then they should not have been learnt to the same extent as the elements that were previously overselected. However, an increase in control by these previously underselected elements at a later stage, despite no further learning, suggests that they must have been learnt to the same extent initially.

If all elements of a compound stimulus are initially learnt, even when the compound stimulus is comprised of as many as three elements, why is equal control of all elements not seen the first time participants are tested with individual elements? Gibson and Reed (2005) incorporated theory by Matzel, Schachtman, and Miller (1985) - who also found emergence
of underselected stimuli when overselected stimuli were put in extinction in a discrimination procedure with rats – to formulate an overshadowing account of the overselectivity effect. They argue that certain elements are overselected because their large salience overshadows that of other elements that are relatively less salient. Putting an overselected element in extinction results in a process of devaluation whereby the salience associated with that element diminishes, thus making previously overshadowed elements more salient relative to before (Reed, Reynolds, & Fernandel, 2012). Because previously underselected elements become more salient as a result of this extinction procedure, these elements come to control behaviour to a greater extent relative to when they were less salient.

This emergence of control by previously underselected elements is not seen for elderly individuals. McHugh and Reed (2007) trained individuals of varying ages to discriminate between two two-element compound stimuli while requiring them simultaneously to remember the configuration of four objects in a grid, akin to the study by Reed and Gibson (2005; Experiment 2A). In a test phase, they were simultaneously presented with one element of the incorrect compound stimulus and one element of the correct compound stimulus. The data was organised according to the age groups of the participants. While all groups showed evidence of overselectivity, only the two younger groups (aged 18 to 22 and 47 to 55) demonstrated emergence of control after the previously overselected element for each individual was punished in a second training phase. The older group (aged 70 to 80) did not. McHugh and Reed argued that the older group did not demonstrate emergence for previously underselected elements because they had never attended to or learnt these elements when the compound stimuli were presented in the training phase. This discrepancy of findings between different populations does not allow for a parsimonious model to explain all findings in the literature.

In any case, the findings of previous research favours an overshadowing account for
explaining the overselectivity effect in individuals of young- and middle-age who either do or do not have autism. However, while previous research suggests that certain elements are overselected over other elements because of their larger salience, little has been done to ascertain what makes overselected elements more salient than others when they do not appear intrinsically more salient than elements that are underselected. Furthermore, little has been done to control or predict which elements of a compound stimulus will be overselected.

Leader, Loughnane, McMoreland & Reed (2009) published the only study on the overselectivity effect in which the salience of elements was manipulated. They ran a typical overselectivity and emergence procedure with one group of children who had autism and one group of children who did not, using two-element stimuli that were each comprised of two distinct colours (i.e., there were four distinct colours in total). In a training phase, the participants were required to select one of two compound stimuli (“AB” rather than “CD”). The colours used were the same for all participants, but for half of the participants in each group, the two colours used for the correct compound stimulus (i.e., “AB”) were not of equal salience - the saturation of one colour was reduced, lowering its intensity. For the other half of participants in each group, the correct compound stimulus that they were presented with contained two elements of equal salience. The training phase was followed by a test phase in which one element of each stimulus was presented on each trial, with participants being required to select one element. An overshadowing account would suggest that the unequal salience group would be more likely to demonstrate overselectivity relative to the equal salience group, because there would be obvious differences in how salient each element was for this group. The individuals who did not have autism did not demonstrate overselectivity irrespective of whether they were allocated to an equal or unequal salience group. For the individuals who had autism, however, those assigned to the equal salience condition did not demonstrate any overselectivity, and those assigned to the unequal salience condition did.
The latter selected one element on significantly more occasions than the other element. A subsequent experiment established that an element was overselected because it overshadowed the other element; control by the previously underselected element emerged in a second test phase when the previously overselected element was put in extinction.

Leader et al.’s (2009) findings are consistent with an overshadowing account of the overselectivity effect because an element of higher saturation would be expected to be more salient than an element of lower saturation. This study cannot explain, however, why certain elements over others have been overselected in previous studies when different elements did not appear to differ along any obvious dimension that might make one element intrinsically more salient than others. Broomfield et al. (2008; Experiment 1), for instance, provided compound stimuli comprised of symbols that were of the same form, shape, colour, intensity, etc., so one should not have been intrinsically more salient than the other. Furthermore, if one element was intrinsically more salient in the previous research, it should have been systematically overselected by all individuals. However, Broomfield et al. did not find that the same element was consistently overselected. Nor did Lovaas and Schreibman (1971), who found that some children overselected the white noise while some overselected the red floodlight. In Reynold’s (1961) study with birds, neither the red colour nor triangle of the stimulus associated with the VI schedule could have been intrinsically more salient given that one bird overselected the red colour whereas the other bird overselected the triangle.

If certain elements are overselected because they are more salient than others, why is overselectivity for certain elements seen in multiple studies when elements that constitute a compound stimulus are of the same apparent salience? One hypothesis is that some other factor changes the salience of certain elements, which makes them more likely to overshadow other elements. Perhaps overselected elements are more salient than underselected elements because they have been associated with a greater magnitude or more frequent reinforcement.
in the organism’s individual learning history. This seems a reasonable hypothesis when the standard emergence procedure in the overselectivity literature is considered. Behaviour can be made to come under greater control of previously underselected elements by punishing or putting in extinction a previously overselected element or reinforcing a previously underselected element. If behaviour can come under greater control of a previously underselected element, this must be because the salience of the stimulus changes. Given that the amount of reinforcement associated with that stimulus has changed in an extinction phase of these experiments, this have changed the salience of the stimulus. If putting an element in extinction results in less control by that element, and if selectivity for an element is determined by its salience, this would suggest that the salience of an element can be decreased by associating it with extinction. It seems reasonable to also assume that the salience of a stimuli can be increased if it is has been associated with more reinforcement in the past.

Schultz (2015) argues that rewards that have been associated with a particular stimulus make that stimulus appear more salient to an organism, capturing its attention as a result, equivalent to how a physically intense stimulus (e.g., a bright light, loud noise, etc.) appears very salient and therefore captures the attention of an organism. The idea that a stimulus associated with reward will have enhanced salience, and therefore capture attention, is supported by some studies. Anderson, Laurent, and Yantis (2011; Experiment 1), for instance, presented participants with six stimuli simultaneously each trial in a training phase. Each stimulus contained a line of a particular orientation. Participants were required to select a stimulus that contained a particular oriented line which was also illuminated either red or green each trial. Doing so resulted in a monetary reward that varied according to the stimulus’s colour on a given trial; that is, selection of the correct stimulus when it was illuminated one colour would result in either a more likely high reward or a less likely low
reward, and selection of the correct stimulus when it was illuminated the other colour resulted in either a more likely low reward or a less likely high reward. In a subsequent test phase, participants also searched for a stimulus that contained a particular line orientation. This stimulus was illuminated a colour that was not red or green. A distractor stimulus, however, that was presented on half of the test trials, was illuminated red or green. Participants were significantly slower at selecting the target stimulus when a distractor stimulus was both present and illuminated the colour previously associated with the more frequent higher reward. This indicated that the reward previously associated with a colour was more salient than the target stimulus, slowing their reaction time on the task as a result. These findings argue against the notion that increased attention directed towards the stimulus was attributable to a top-down allocation of attention (and not due to bottom-up high-salience attention-capturing stimuli). If this was the case, the top-down allocation of attention would be directed towards the stimuli that was correct in the current task. Given that attention was directed towards a stimulus that was not relevant to the task, it suggests that the attention allocated to this stimulus was the result of a bottom-up salience-driven process, which was attributable to the prior reward. The findings of this study are also important because they show that stimuli previously associated with prior rewards appear more salient to individuals under test conditions in which these stimuli are no longer associated with a large reward.

Stimuli previously associated with a history of reward appear to be more salient to individuals and prime them into having their behaviour controlled by them. This is so even when the benefit for having their behaviour controlled by that element no longer exists and even when that stimulus is not intrinsically more salient than other presented stimuli. Further evidence that a stimulus may be more salient than other simultaneously presented stimuli that are not intrinsically more salient, and that a stimulus may control behaviour despite attention or other behaviour being directed elsewhere, is the widely researched “Cocktail Party” effect.
Conway, Cowan, & Bunting (2001) describe this phenomenon as individuals hearing their name mentioned elsewhere in conversation despite their attention being directed towards an alternate activity. This occurs even when the decibels of the uttered name are no different than the decibels of the uttered words either side of the name and even when the other words are hard to distinguish. This phenomenon may be explained behaviourally. Because past reinforcement has been contingent on behaviour that occurs in response to an individual’s name, the name acts as an antecedent stimulus for multiple environmental contingencies for that individual. As a result, the name stands out more when interspersed among other stimuli (words either side of the person’s name) that are not intrinsically more salient and have not been associated with much reinforcement in the individual’s learning history.

If behaviour can come under the enhanced control of a stimulus solely because that stimulus has been associated with more reinforcement in the individual’s learning history, then this mechanism could determine which element of a compound stimulus will be overselected as well. Elements previously associated with more reinforcement should be overselected because that element’s salience has increased on account of the previous reinforcement. To test this hypothesis, the present experiment combined paradigms used to demonstrate an overselectivity effect with priming paradigms used in cognitive psychological research. The procedure was similar to that of previous studies examining the overselectivity effect, but added a preliminary visual search task, in which individuals were required to find a distinct element in an array of identical elements. The size of the reward for correctly selecting the distinct element depended on the colour that the distinct element contained each trial, so that differential colour-reward associations would be learnt. Then, in a training phase, individuals made discriminations between compound stimuli, with each element of these compound stimuli containing a colour that the distinct element had contained in the visual search task. A test phase followed, in which participants were presented with elements from
each compound stimulus and required to make a response. Participants should be more likely to overselect the element that contained the colour previously associated with the highest magnitude of reward. An extinction procedure, in which the element expected to be overselected was put in extinction, and a second test phase followed. This was done to determine whether emergence would be seen for the element put in extinction. Evidence of this would suggest that the larger reward associated with the colour of that element had caused it to become more salient and overshadow other elements, rather than merely enhance attention towards it.
Experiment 1

In order to both induce an overselectivity effect and test for an effect of reward history, a standard discrimination procedure was implemented akin to the designs of previous studies. First, a preliminary visual search was implemented before the training phase in order to associate particular colours with differential rewards. Then, participants were trained to discriminate between two six-element compound stimuli, and then presented with individual elements of each stimulus. Any overselectivity for an element that contained a colour previously associated with the highest reward in the visual search would suggest an effect of reward history. An extinction phase followed, where the element predicted to be overselected (i.e., the element containing the colour associated with the highest magnitude of reward) was put in extinction. A second test phase followed to test for emergence. Evidence of this would suggest that the element containing the colour associated with the highest reward was overselected because the higher reward had made it more salient, and not just triggered more attention towards it.

Method

Participants. The 10 participants were psychology undergraduates from the University of Otago, whose ages ranged from 18 to 22. Six were female and four male. All individuals participated as part of an optional piece of assessment. None suffered from colour-blindness.

Materials. All participants were presented with a Java program on computers in a psychology laboratory. The program was displayed on screens of a 1920 x 1080 resolution. The program presented all trials of each phase to participants, and recorded the stimuli that were presented and responses made for each trial. Participants made responses using a computer mouse.
Procedure. The experiment consisted of five phases. Throughout, participants were informed that more accurate performance would be rewarded with fewer trials to complete across the entire experiment. In fact, Phases 1, 3, and 5 lasted a fixed number of trials before the next would begin. In Phases 2 and 4, participants were required to achieve a successive number of correct responses before they could continue to the next phase. Participants received instructions at the beginning of each phase.

**Phase 1 – Visual Search Phase.** Before trials commenced for this phase, participants received the following instructions:

*Thank you for agreeing to take part in this experiment. Please read the following instructions carefully. This experiment consists of several parts to be completed one after the other.*

*In Part One, each trial starts with a group of 6 images in the centre of the screen. They will disappear after a few seconds. 1 of these images will be different from the other 5. You must click on this image.*

*There are 15000 trials over the entire experiment, but each correct choice reduces the number of trials you need to complete by a larger amount – THIS MEANS THAT THE MORE ACCURATE YOU ARE, THE SOONER YOU CAN LEAVE. The number of trials deducted for correct responses varies from trial to trial.*

*If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button below to begin the experiment.*

For each trial, after a 2s pause, a stimulus was displayed on the screen (Figure 1). This stimulus contained six elements, arranged in a two by three configuration. The images of five of these elements were identical, and the image of one was distinct. The two unique images
on each trial were selected randomly from a subset of Snodgrass and Vanderwart’s (1980) stimulus set. Additionally, each of the six elements contained a unique colour such that no two elements shared the same colour. While the elements’ images varied from trial to trial, the set of colours was the same, but each element could contain any colour on a given trial. The position of each colour was randomly determined each trial. While the images that were obtained and locations of the colours were randomly determined each trial, the colour the distinct element contained in a trial was determined pseudorandomly, such that the distinct element contained each colour an equal amount of times.

Participants were required to click the distinct element using the mouse. This selection had to be made within 2s of stimulus onset; the stimulus would disappear after this time. If the correct element was selected, the stimulus would disappear, and a message was presented on the screen saying that the selection was correct and that a certain number of trials was deducted from the experiment (“Correct! X trials off!). The number of trials deducted depended on the colour of the distinct element; each of the six colours (green, yellow, cyan, orange, magenta, and grey) was associated with a unique reward (deductions of 5, 10, 15, 30, 45, or 200 trials) for each participant prior to the start of the experiment. For instance, for one participant, the colour yellow might have been associated with a deduction of 200 trials, while the colour cyan might have been associated with a deduction of 15 trials. Therefore, for this participant, a correct selection of the distinct element when it contained cyan deducted 15 trials from the experiment; in a different trial, a correct selection of the distinct element when it contained yellow deducted 200 trials. Each colour was assigned to one of six possible rewards randomly, such that any colour might be the most rewarded for each participant. This meant that the same colours would be associated with different rewards for different participants. This controlled for the possibility that certain colours may have been more salient for certain individuals.
If the participant selected one of the five identical elements in a trial, the stimulus would also disappear, but an incorrect message would display on the screen (“Incorrect!”). The same was true if no selection was made within 2s of stimulus onset, except that the displayed message would direct the participant to make a faster selection (“Be quicker with your response”). In all cases, the relevant message was displayed for 2s before the next trial commenced. For each trial, the program recorded the colour that the distinct element contained and whether or not a correct, incorrect, or no selection was made. This procedure lasted for a total of 240 trials (i.e., the distinct element contained each colour 40 times). The next phase then commenced.

**Phase 2 – Training Phase.** Before the trials began in this phase, the following instructions were displayed on the screen:

*In Part Two, two groups of 6 images will appear on the screen for a few seconds; one on the left, the other on the right. The same two groups appear each trial, but the images within each group will be jumbled around each trial. One group will always be correct, and the other group will always be incorrect. You must click on the*
correct group before the two groups disappear. Whenever you select the correct
group, the trials remaining will reduce by 30.

At first you must guess which group is correct, but after that it should be obvious
which group is correct from then on.

If anything is not clear, please ask experimenter. Otherwise, if you understand the
instructions, please press the “Start” button to proceed to the next part of the
experiment.

In each trial of this phase, after a 2s pause, two compound stimuli were displayed
simultaneously on the left and right of the screen (Figure 2). The stimuli were identical in
format to the group of stimuli presented each trial in Phase 1; each stimulus was comprised of
six elements displayed in a formation of two rows of three. Their contents were different,
however. Each element of each stimulus contained an image taken randomly from the
stimulus set. However, the two stimuli shared no elements. Similar to Phase 1, each element
of each stimulus contained a unique colour (the six colours were the same as those used in
Phase 1), such that each element of each stimulus shared the same colour with one element of
the other stimulus.

The same two stimuli were presented each trial; that is, each stimulus contained the
same elements that it had on previous trials. However, the positions of elements within each
stimulus would change from trial to trial. This prevented the possibility that participants were
controlled by elements purely because of their position in the stimulus. One of the stimuli
was assigned as the correct stimulus (Stimulus A) across all trials of this phase, and the other
stimulus was assigned as the incorrect stimulus (Stimulus B) across all trials of this phase.

For each trial, Stimulus A would either be presented on the left or right of the screen
(the left-right position was randomly determined to insure that correct responses were not
controlled by the location of the correct stimulus). Participants performed correctly for a trial by clicking anywhere on Stimulus A and incorrectly if they clicked anywhere on Stimulus B. If the participant selected Stimulus A, both stimuli were removed from the screen, and a message was presented saying that a correct selection was made and that 30 trials had been deducted from the experiment (“Correct! 30 trials off!”). If the participant selected Stimulus B, both stimuli were removed and the message stated that an incorrect selection had been made (“Incorrect!”). If neither stimulus was selected in the 2s after stimulus onset, the stimuli were removed and the message directed participants to make a faster response (“Be quicker with your response.”). The program recorded whether the participant made a correct or incorrect selection each trial, the total number of trials, and the number of trials correct for this phase. This phase ended when participants selected Stimulus A on 10 successive trials.

**Phase 3 – Test Phase One.** The following instructions were displayed on the screen before the trials began for this phase:

*In Part Three, two images will appear on the screen for two seconds, one on the left and one on the right. One image will be one of the images from the correct group in Part Two (that you have just completed). The other image comes from the incorrect*
group in Part Two. You must click the image from the previous “correct” group; whenever you do, 30 trials will be deducted from the total trials remaining. Different images from the two groups will be used each trial.

Unlike Parts One and Two, you WILL NOT be told if you were correct or not, and the total number of trials remaining will not appear on the screen. However, correct responses will still reduce the total trials remaining, even though you won’t be told

If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button to proceed to the next part of the experiment.

For each trial, after a 2s pause, two elements were presented simultaneously on the left and right of the screen (Figure 3). One of these elements was from Stimulus A, and the other an element from Stimulus B. The left-right position of the correct element (the element from Stimulus A) was randomly determined each trial.

Participants were instructed each trial to select the element that had been part of Stimulus A in Phase 2. Because this was a test phase and run to determine which element or elements of Stimulus A had controlled the participants’ responses in Phase 2, the participants

Figure 3. An example of two elements that were displayed for a participant on a Phase 3 trial. One element, the lips, is from the correct training stimulus shown in Figure 2 and the other element, the carrot, is from the other training stimulus shown in Figure 2. Each element contains the same colour they contained when part of the stimuli in Phase 2.
received no feedback on whether or not they performed correctly on a given trial. However, to assure that participants were not making selections at random, they were informed that selection of the element from Stimulus A would result in a reward of a deduction of trials. If either element was selected, the elements disappeared, and after 2s, the next trial commenced. If, after 2s, neither element was selected, the elements were removed from the screen, and a message appeared directing participants to make a faster selection (“Be quicker with your response.”). On each trial, the program recorded the elements presented, the colour the element from Stimulus A contained, and which element that was selected or whether no element was selected. Given that each stimulus was comprised of six elements, any of thirty-six possible combinations of elements could be displayed on a given trial. All 36 combinations were presented in a pseudorandom sequence three times; a total of 108 trials before the next phase commenced.

**Phase 4 – Extinction Phase.** The following instructions were displayed on the screen before the trials started for this phase:

*In Part Four, two images will appear each trial, one on the left and one on the right. One of these images will be the SAME on each trial. This is the INCORRECT image. The other image will be NEW – it has not been used in Parts One, Two, or Three. This will always be the CORRECT image. If you click this image, then you will reduce the total trials remaining by 30.*

*You WILL be told if you were correct or not, and the total number of trials remaining will be shown.*

*If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button to proceed to the next part of the experiment.*
For every trial, the same two elements were presented (Figure 4) after a 2s pause. One was the element from Stimulus A that contained the colour previously associated with the highest reward in Phase 1. It was displayed with its colour in this phase. The other was a novel element with no colour that was not part of either Stimulus A or Stimulus B. The elements were presented simultaneously for 2s, with the left-right position of each being randomly determined.

Feedback was given in this phase. If the novel element (the correct element in this phase) was selected, both elements disappeared and were replaced with a message stating that they had performed the trial correctly and had 30 trials deducted (“Correct! 30 trials off!”). The same was true if the element from Stimulus A was selected, but the message stated that they had performed the trial incorrectly (“Incorrect!”). If neither element was selected after 2s of the elements being presented, the elements disappeared and a message appeared directing the participant to make a faster response (“Be quicker with your response.”). Participants progressed to the next phase of the experiment after they had selected the novel element on 10 successive trials. The program recorded the total number of trials that took

Figure 4. An example of the elements displayed for a participant on a Phase 4 trial. The snake element is an element of the correct training stimulus displayed in Figure 2. Because it is being displayed in this phase, this indicates that it contains the colour previously associated with the highest magnitude of reward in Phase 1. The broom element was not part of either training stimuli shown in Figure 2. This is the novel element that is reinforced in this phase.
place for this phase, and how many of these trials were performed correctly.

**Phase 5 – Test Phase Two.** This phase was a repeat of Phase 3.

**Results**

**Phase 1 – Visual Search Phase.** Participants were expected to learn the associations between the different colours and magnitudes of reward, such that certain elements of the correct training stimulus would appear more salient in Phase 2. Some participants, however, did not consistently select the distinct element throughout this phase. A criterion was set at 80% correct for each of the colours that the distinct stimulus contained. Nine of the ten participants reached this criterion. The remaining participant’s data were not used in subsequent analyses.

**Phase 2 – Training Phase.** Overall, the participants learnt the discrimination quickly. The mean number of trials taken to reach criterion of 10 successive correct responses was 14.89 \((SD = 4.99)\), with a range from 10 to 26 trials.

**Phase 3 – Test Phase One.** This phase tested whether participants selected certain elements of Stimulus A on more trials than other elements of Stimulus A, and whether the overselected elements contained colours previously associated with the highest magnitudes of reward. The proportion of trials in which the element from Stimulus A was selected that contained the colour previously associated with the highest magnitude of reward was calculated, followed by the proportion of trials in which the element from Stimulus A was selected that contained the colour previously associated with the second highest magnitude of reward, and so on. These proportions were averaged across the group of participants to give mean proportions of trials correct for each element of Stimulus A. Figure 5 shows the result of this analysis.

If there was an effect of reward history, then elements containing colours that had previously been associated with the higher rewards (1st, 2nd and 3rd in Figure 5) should be
Figure 5. Mean proportion of trials in which each element of Stimulus A was selected in Phase 3, in order of the magnitude of reward previously associated with the colour of each element.

selected at higher proportions than the elements containing colours previously associated with the lower rewards (4th, 5th and 6th in Figure 5). Figure 5 shows that all elements were selected at relatively even proportions. The results of a Repeated-Measures One-Way Analysis of Variance (ANOVA) test were not significant \( F(2.89, 23.15) = 0.48, p = 0.69 \), indicating no difference in the proportion of trials in which the elements were selected. Thus, there was no effect of reward history.

Although Figure 5 shows no evidence of systematic overselectivity as a function of reward history, it is possible that participants displayed overselectivity unrelated to the rewards previously associated with the colour of each element. Evidence of this would suggest that the lack of an effect of reward history was not because an overselectivity effect was not present. The individual participant data was examined in order to ascertain whether
participants showed any evidence of overselectivity. The individual data is displayed in Table 1.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Element 1</th>
<th>Element 2</th>
<th>Element 3</th>
<th>Element 4</th>
<th>Element 5</th>
<th>Element 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.93</td>
<td>1.00</td>
<td>0.95</td>
<td>1.00</td>
<td>0.88</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
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<td>0.59</td>
<td>0.50</td>
<td>0.44</td>
<td>0.37</td>
<td>0.40</td>
</tr>
<tr>
<td>10</td>
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<td>0.90</td>
<td>0.83</td>
<td>0.94</td>
<td>0.68</td>
<td>0.88</td>
</tr>
<tr>
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<td>0.95</td>
<td>0.67</td>
<td>0.94</td>
<td>1.00</td>
<td>0.43</td>
</tr>
<tr>
<td>12</td>
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<td>0.53</td>
<td>0.67</td>
<td>0.54</td>
<td>1.00</td>
<td>0.88</td>
</tr>
<tr>
<td>13</td>
<td>0.81</td>
<td>1.00</td>
<td>1.00</td>
<td>0.54</td>
<td>0.75</td>
<td>0.61</td>
</tr>
<tr>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.94</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
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<td>1.00</td>
<td>0.94</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>18</td>
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<td>0.93</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Note:* Element 1 contained the colour previously associated with the highest magnitude of reward.

Table 1 indicates that four participants – Participants 7, 15, 17, and 18 – demonstrated equally high selectivity for all six elements, and that one participant – Participant 9 – demonstrated equally low selectivity, at chance levels, for all of the elements; that is, five of the nine participants did not demonstrate any evidence of overselectivity. The remaining four participants – Participants 10, 11, 12 and 13 – however, did show overselectivity; they demonstrated high selectivity for some, but not all, elements, and a large difference between the proportions of trials in which the most often and least often selected elements were selected. This is more evident from Figure 6, which shows the proportion of trials in which
each element was selected for the four individuals that demonstrated overselectivity in order of the most to least selected element. Figure 6 clearly demonstrates large differentials in the proportion of trials in which different elements of Stimulus A were selected. This is most evident by comparing between the most and least often selected element for each participant. Participant 11 showed the largest differential of 0.57 between the most and least often

![Graph showing selectivity](image)

**Figure 6.** Proportions of trials in which each element of Stimulus A was selected in Phase 3, from the most to the least often selected element, for the four individuals that demonstrated overselectivity in Phase 3.

selected elements. The differentials shown by other participants were smaller, but still quite large, at 0.47, 0.46, and 0.27, for Participants 12, 13, and 10, respectively. Overselectivity was also evidenced by the fact that these participants only showed high levels of selectivity for a few, rather than all, elements. For instance, Participant 10 appeared to show similarly high levels of selectivity for only four elements; Participant 11 only three; Participant 13 only
two; and Participant 12 only one. Thus, because an overselectivity effect was clearly present in some of the participants, a lack of an effect of reward history was not attributable to the fact that an overselectivity effect was absent.

The individual data were also examined to see whether there was an effect of reward history when only the participants’ data that demonstrated overselectivity was considered. Figure 7 shows the proportions of trials in which each element was selected when data was organised according to the magnitude of reward previously associated with the colour of each element, for the four individuals that demonstrated overselectivity. If there was any effect of reward history, there would be the most selectivity for the elements containing colours previously associated with the highest rewards and progressively less selectivity for elements with the lower magnitudes of reward. Of the participants that demonstrated overselectivity,

![Graph](image)

Figure 7. Proportion of trials in which each element of Stimulus A was selected in Phase 3 in order of the magnitude of reward previously associated with the colour of each element, for the four participants that demonstrated overselectivity in Phase 3.
only Participant 10 selected at the highest level the element that contained the colour previously associated with the highest reward (Element 1). Even with this participant, however, the level at which they selected this element was relatively equal with the level at which they selected the elements containing colours previously associated with the fourth (Element 4) and sixth (Element 6) highest rewards. Participant 13 did show higher selectivity for the three elements containing colours previously associated with the highest rewards (Elements 1, 2, and 3) and lower selectivity for the three elements containing colours previously associated with the lower rewards (Elements 4, 5, and 6). However, none of the other participants demonstrated the same pattern of overselectivity. In fact, Participants 11 and 12 demonstrated much higher levels of selectivity for elements that contained colours previously associated with low rewards (Element 4 and 5 for Participant 11; and Element 5 for Participant 12) relative to the element that contained the colour previously associated with the highest reward (Element 1). Together, this provides more evidence against there being an effect of reward history on overselectivity.

**Phase 4 – Extinction Phase.** This phase took the element containing the colour previously associated with the highest magnitude of reward and put it in extinction. The participants learnt the discrimination in this phase quickly; taking only an average of 10.11 (SD = 0.33) trials to reach the criterion of 10 correct successive responses with a narrow range from 10 to 11 trials.

**Phase 5 – Test Phase Two.** This phase was run in order to determine if the level of overselectivity seen for the previously most overselected element in Phase 3 would diminish and if emergence would be seen for elements that had been previously underselected. However, because the element predicted to be overselected was often not the overselected element, a relatively underselected element was often put in extinction in Phase 4. Therefore, the effect that this had on the selectivity for each element could be examined.
It was of interest to see whether the four participants that showed overselectivity in Phase 3 still showed overselectivity in Phase 5 after the extinction procedure, and how selectivity changed as a function of the extinction procedure. Figure 8 shows the proportion of trials in which the same elements were selected in Phases 3 and 5 for the participants that demonstrated overselectivity in Phase 3. Two of these participants - Participants 10 and 12 - no longer showed overselectivity in this phase; where, in Phase 3, Participants 10 and 12 had shown equally high levels of selectivity for only two and one elements, respectively, they showed equally high levels of selectivity for all elements in Phase 5. Participants 11 and 13, in contrast, did still show evidence of overselectivity. The differentials in the proportion of trials in which the most and least often selected element were selected in Phase 5 for Participants 11 and 13 were still quite similar to the differentials they showed in Phase 3, at 0.42 and 0.49, respectively. Furthermore, they did not demonstrate equally high levels of selectivity for all elements. However, the degree of overselectivity they showed in Phase 5 was less than in Phase 3 because they showed equally high selectivity for more elements in Phase 5 relative to Phase 3, with less elements being underselected. For instance, Participant 11 showed equally high levels of selectivity for three elements in Phase 3, but for five in Phase 5. Similarly, Participant 13 showed equally high levels of selectivity for two elements in Phase 3, but for three in Phase 5. Thus, all participants showed less overselectivity in Phase 5 relative to Phase 3.

This reduction in overselectivity for the four participants that showed overselectivity in Phase 3 occurred despite the fact that for three participants (Participants 11, 12, and 13) the element put in extinction (Element 1) in Phase 4 was not the element that had been most often selected in Phase 3 (the element put in extinction was the fifth most selected element for Participant 11 in Phase 3; the third most selected for Participant 12; and the third most selected for Participant 13). Furthermore, three of the four participants actually showed an
increase in selectivity for this element. Only Participant 13 showed a decrease in the level of selectivity from Phase 3 to Phase 5 for the element that was put under extinction (this element was also relatively underselected in Phase 3 for this participant). Thus, there was evidence of emergence irrespective of how often the element that was put in extinction had been selected in Phase 3, and in some instances selectivity for this element increased.

The increases in selectivity for some elements from Phase 3 to Phase 5 also occurred despite the fact that some of these elements had been selected more often compared to the element that was put in extinction. For instance, Participant 11 demonstrated a large increase in selectivity from Phase 3 to Phase 5 for Element 3 and Participant 12 demonstrated a small increase in selectivity for Element 6, despite the fact that these elements were selected at

\[\text{Figure 8. Proportion of trials the same elements of Stimulus A were selected in Phases 3 and 5, in order of the magnitude of reward previously associated with the colour of each element, for the four participants that demonstrated overselectivity in Phase 3. Element 1 was the element put in extinction for all participants.}\]
higher levels in Phase 3 relative to the element put in extinction (Element 1).

Discussion

Experiment 1 was conducted to determine whether elements of a compound stimulus that contained colours that had been previously associated with larger rewards would be overselected more often relative to elements that contained colours previously associated with smaller rewards. The study then sought to determine that this effect was due to the colours previously associated with the larger rewards enhancing the salience of the element they were contained within, rather than just enhancing attention towards them. This would be evidenced by an increase in the level control by elements that were previously underselected after the most selected element was put in extinction. While overselectivity was observed in the first test phase (Phase 3) of the experiment, there was no element in particular that was consistently overselected; that is, the reward previously associated with each element’s colour had no effect on which element was overselected. The hypothesis that overselectivity for particular elements would depend on the reward previously associated with the colours they contained was, therefore, not supported.

While the amount of overselectivity was unrelated to the amount of reward that had been previously associated with the colour of each element, an overselectivity effect was nevertheless still observed for some participants. As this occurred without the need for a simultaneously-run distractor task, Experiment 1, therefore, systematically replicated earlier studies (e.g., Broomfield et al. 2008; Experiment 1) that have found that presenting a compound stimulus comprised of a larger number of elements is enough to induce an overselectivity effect for some individuals.

Because it was expected that the element that contained the colour previously
associated with the highest reward would be overselected, it was this element that was put in extinction for each participant. In many instances, however, the most overselected element was an element that contained a colour previously associated with a lower reward, so a relatively underselected element was put in extinction for many participants. In fact, Figure 8 indicates that of the four participants that showed overselectivity, the third most selected element was put in extinction for two participants, and the fifth most selected element was put in extinction for another. Only one participant had their most selected element put in extinction. This had no effect on whether emergence for many of the previously underselected elements was seen, however; these participants all showed more equal selectivity for all elements in the second test phase (Phase 5), irrespective of which element was put in extinction. This result is surprising. Previous studies (Broomfield et al., 2008; Broomfield et al., 2010; Reed et al., 2012) have demonstrated emergence of previously underselected elements only after the most overselected element is put in extinction. The overshadowing account of the overselectivity effect suggests that putting a previously overselected element in extinction decreases its relative salience, allowing previously underselected elements to be less overshadowed relative to when they were first observed as part of a compound stimulus (Reed et al.). The present results are still consistent with an overshadowing account of the overselectivity effect, however. Elements that were previously underselected would still have had some salience, even if less than the salience a previously overselected element would have had. If decreasing the salience of a more salient element results in an increase in the relative salience of a less salient element, then one would expect that decreasing the salience of a previously underselected element might also result in an increase in the relative salience of a previously overselected element (provided, of course, that the previously overselected element had not already reached the maximum salience).
The overshadowing account cannot explain, however, why three of the four participants that demonstrated overselectivity in the first test phase (Phase 3) showed an increase in selectivity for the element put in extinction from the first to the second test phase (Phase 5), rather than a decrease. This is inconsistent both with previous findings (e.g., Broomfield et al., 2008; Experiment 1), where control by previously overselected elements decreased significantly from a first to a second test phase after being put in extinction, and the theory thought to explain why emergence occurs. An overshadowing account predicts that the extinction of an element should result in a loss of salience for that element, and, therefore, a subsequent decrease in control by that element. Additionally, the findings of previous research (Broomfield et al., 2008; Broomfield et al., 2010; Reed et al., 2012) have indicated that gains in salience, and, therefore, selectivity for certain elements on account of an extinction procedure, are offset by losses in salience and selectivity for other elements through a zero-sum mechanism. If certain elements overshadow others elements through having more salience, then a gain in salience of one element must have occurred because another element can no longer overshadow that element to the same extent; that is, another element’s salience must have reduced. An overshadowing account, therefore, predicts that increases in the selectivity for one element cannot occur without decreases in the selectivity of another element. In many instances, however, participants demonstrated increases in selectivity from the first to the second test phase without any accompanying decreases in selectivity of other elements. In fact, Figure 8 shows that Participants 10 and 12 showed no decreases in selectivity of any elements given that they improved to show equally high selectivity for all elements in the second test phase.

It is possible to provide some explanations for the present findings, but it is unlikely that these explanations are consistent with an overshadowing account of the overselectivity effect. If emergence of relatively underselected elements can be induced irrespective of
whether that element or another was put in extinction, emergence might occur simply as a result of running a second test phase (Phase 5), irrespective of what occurs between the first (Phase 3) and second test phase. One reason could be practice effects. During the first test phase, participants might perform inaccurately for some of the elements, but then perform more accurately for these elements in the second test phase due to being better versed with the task. Broomfield et al. (2008; Experiment 2) provide evidence against this notion. Similarly to Broomfield et al. (2008; Experiment 1), an overselectivity effect was induced in participants through a MTS task. For an experimental group’s procedure, the previously most overselected element was put in extinction between two MTS phases. A control group was exposed to the same procedure, but they experienced no extinction phase between MTS phases. From the first to the second MTS phase, the control group did show a small increase in the extent to which they selected a previously underselected element and a small decrease in the extent to which they selected the previously most overselected element, but these differences were not significantly different from zero. These differences were significantly different from zero for the experimental group, however. If emergence of previously underselected elements is solely due to practice effects, increases in selectivity for previously underselected elements should have been seen for the control group as well, as the lack of an extinction phase should not hinder their ability to be more practiced with the task. In addition, if the results were attributable to practice effects, selectivity for the previously most overselected element should not have decreased from the first to the second MTS phase. This study, and other studies that have also shown no change in the selectivity of elements when a control group is not exposed to an extinction phase between test phases (e.g., Reed et al., 2012), suggest that running the extinction phase, irrespective of the element that is put in extinction, is more likely to have caused the emergence of previously underselected elements in the current study.
An explanation of the findings of Experiment 1 that is still consistent with an overshadowing account is difficult to find. The overshadowing account predicts that emergence should only occur for certain elements (elements that have not been put in extinction) and under certain conditions (when there is a decrease in control by other elements). Given that the findings of the current study provide evidence inconsistent with these predictions, and because evidence of emergence is often used as a basis to dismiss an attentional account of the overselectivity effect (e.g., Broomfield et al., 2008; Broomfield et al., 2010), the findings of the current study might suggest that an attentional account has more merit at this point.

In any case, why did reward history have no effect on overselectivity in Experiment 1? It could be that reward histories do not effect which element of a compound stimulus will be overselected. Alternatively, they do, but the procedure’s design may have not allowed an effect of reward history to be induced. There are several reasons for this, some of which are related to the number of elements comprising the compound stimuli. First, an effect of reward history depended on associations between the different colours and different rewards being learnt in the visual search (Phase 1). The more trials in this phase, the more likely that colours previously associated with more reward would appear more salient for participants during training (Phase 2). For example, Anderson et al. (2011; Experiment 1) associated a colour with a more frequent higher reward for 504 trials before finding that, later, a target stimulus containing that colour appeared more salient and triggered attention of participants towards it. Although associating each colour with a reward for 504 trials may not have been necessary for certain colours to appear more salient to participants during training, 40 trials for each colour in the visual search phase may not have been sufficient for this effect to occur.

Second, because the compound stimuli were comprised of six elements, these stimuli took up a large amount of space on the screen during training (Figure 2). It is possible that on
the first trial in which the participant selected the correct stimulus, they may have fixated on
the innermost elements of each compound stimuli, rather than towards the element that
contained the colour previously associated with the most reward. This fixation might have
been more natural or easier. This could explain why any element was just as likely to be
overselected, irrespective of the reward associated with it, because any element could have
been presented for the innermost element for the first trials of this phase. No data was
collected for this, however, so this would be impossible to examine. The reward histories
might have some effect if compound stimuli were comprised of fewer elements, placed on
top of the other, rather than side by side, in the middle of the screen. With this configuration,
eyes would have to orient the same distance to fixate on each element of a compound
stimulus, given that all elements of each stimulus would be the same distance away from the
other stimulus. In addition, a larger number of elements in the visual search (Phase 1) and
training (Phase 2) phases may have made it more difficult for participants to learn that
different colours were associated with different reward. Fewer elements, with fewer and more
differentiable rewards, may make an effect of reward history more likely to occur.

Third, the colours provided an extra aid for participants to identify less salient correct
stimulus elements during the first test phase (Phase 3). Say that the cyan correct stimulus
element, A₁, strongly controlled a participant’s behaviour during training (Phase 2), due to
cyan being previously associated with the largest reward. The participant could then easily
determine that the other cyan element, B₁, was incorrect (even if the participant did not notice
this element in training trials), simply because there was only one correct element of each
colour, and one incorrect element of each colour. Because one correct element and one
incorrect element was always presented each trial, the participant could then determine on a
future trial that element A₂, when it was presented with B₁, must be correct. The participant
could determine this even though A₂’s colour (green, for example) did not appear more salient
during training. Thus, participants could learn that less salient elements were correct even if
these elements had not controlled their behaviour during training (Phase 2), and they could
therefore select them at a relatively equal level to highly salient elements during the first test
phase. Therefore, no effect of reward history would be observed in the first test phase. If
elements were presented without colours, participants could not use this strategy to accurately
select less salient elements. Therefore, any high selectivity for any element would be more
likely to be attributable to that element controlling their behaviour during training.

Fourth, because elements contained common objects as images, it may have been easy
for participants to identify in the first test phase (Phase 3) whether or not these elements had
been part of the correct training stimulus. Observing images that resemble real objects in the
environment might make these elements more salient relative to using images that do not
resemble anything. The names of these images (“Spider”, “Ladder”, etc.) could also have
been easily rehearsed when participants were observing them as part of the correct compound
stimuli. These factors may have compensated for the lack of salience an element containing a
colour previously associated with a small reward would have had, and meant that these
elements were equally likely to be selected at a high level. Using images that do not resemble
anything for participants would prevent the likelihood that these elements would be more
salient than the rewards associated with their colours should dictate. Using these types of
images would also prevent the likelihood that participants could rehearse the elements.

Experiment 2

Experiment 2 made four changes to promote overselectivity and an effect of reward
history. First, Experiment 2 arranged compound stimuli comprised of only three elements for
both the visual search (Phase 1) and training (Phase 2). This is because the lack of an effect
of reward history in the prior experiment might have been partially attributable to the large
number of elements used. Second, because a fewer number of elements were used, a
distractor task, similar to the one used by McHugh and Reed (2007), was presented for the duration of training. Previous research (Broomfield et al., 2008) has shown that while it is not necessary to present the compound stimuli in conjunction with a distractor task to exhibit an overselectivity effect if the compound stimuli are comprised of three elements, a substantial proportion of participants still do not demonstrate overselectivity under these conditions. Thus, a distractor task was included in Experiment 2 in to insure that the overselectivity effect would be induced in as many participants as possible. Third, the colours of elements were removed from the test phases (Phases 3 and 5), as these provided an additional aid for making accurate selections unrelated to the control that these elements had over participant’s behaviour during training. Removing these colours from test phases would make an effect of reward history more likely to be observed, given that high selectivity for an element would be due solely to the control that element had over responses in the training phase. Fourth, the objects taken from the Vanderwart and Snodgrass (1980) stimulus set were replaced by Kanji characters. This was done to prevent the possibilities that the common objects made elements more salient and that participants were rehearsing objects when viewing the correct compound stimulus. As the Kanji characters were less likely to represent anything for the participants, rehearsal would be more difficult.

Another reason for conducting Experiment 2 was to see if the findings of Experiment 1 could be replicated, and examined in more detail. Experiment 1 found changes in selectivity for some elements not accompanied by opposite changes in selectivity for other elements, and emergence for elements actually put in extinction. These effects were found in all participants that demonstrated overselectivity in the first test phase (Phase 3). However, only few of the participants in Experiment 1 displayed an overselectivity effect in the first test phase, so the effects of running extinction procedures could only be seen on few participants. If overselectivity could be induced in a larger number of participants, it would be easier to
examine the consistency with which these effects occurred once a second test phase (Phase 5) was presented. They could then be examined in more detail. Consistency of these effects would be problematic for the overshadowing account of the overselectivity effect.

**Method**

**Participants.** Twenty-six participants, none of whom suffered from colour-blindness or were familiar with Kanji characters, were used for the study. Of these participants, 16 were female and 9 were male, with ages ranging from 17 to 48 years. All individuals participated as part of an optional piece of assessment.

**Materials.** A Java program presented the experiment to participants and recorded the stimuli and elements presented on each trial as well as the responses made. Seven Kanji characters were used as elements. The Kanji characters were chosen on the basis of distinguishability to prevent participants mistaking one character for another. The stimuli and elements were presented on a computer screen that had a resolution of 1920 x 1080, and participants made responses on the screen with a computer mouse.

**Procedure.** The experiment consisted of five phases. Participants were informed that they were required to perform a series of tasks before they could leave, but that more accurate performance on each trial of each task would result in deductions in the number of trials that they were required to do. In fact, the number of trials for each part of the experiment was fixed except for Phases 2 and 4, in which a successive number of trials had to be performed correctly before participants could progress to the next phase.

**Phase 1 – Visual Search Phase.** At the start of this phase, participants were presented with the following instructions:
Thank you for agreeing to take part in this experiment. Please read the following instructions carefully. This experiment consists of several parts to be completed one after the other.

In Part One, each trial starts with a group of 3 Kanji characters in the centre of the screen. They will disappear after a few seconds. 1 of these images will be different from the other 2. You must click on this image.

There are 15000 trials over the entire experiment, but each correct choice reduces the number of trials you need to complete by a larger amount – THIS MEANS THAT THE MORE ACCURATE YOU ARE, THE SOONER YOU CAN LEAVE. The number of trials deducted for correct responses varies from trial to trial.

If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button below to begin the experiment.

Figure 9. An example of the type of stimulus presented to a participant on a Phase 1 trial. For this trial, the yellow element is the correct element, given that its character is distinct from the characters of the other two elements. The reward for selecting this element was dependent on the reward that was associated with the colour yellow for this participant.
Each trial, after a 2s pause, a stimulus appeared on the screen for 2s (Figure 9). This stimulus contained three elements, each of which contained a Kanji character. The characters of two of these elements were identical, and one character was distinct. So, two random characters were taken from the set of Kanji characters each trial. Furthermore, each element contained one of three colours: blue, red, or yellow. No element shared a colour with any other element, and these colours would be randomly located to a different position each trial.

On each trial, the participants selected (with a mouseclick) the distinct element within 2s of the stimulus being presented. If the participants selected the correct element, the stimulus disappeared from the screen, and a message appeared on the screen stating that the participant had performed the trial correctly and that a certain number of trials had been deducted (“Correct! X trials off!”). The number of trials deducted depended on the colour that the distinct element contained for that trial. Each of the three colours was associated with one of three rewards (deductions of 10, 20, and 150 trials), such that there were three unique reward-colour associations. So, if for one participant, the red colour was associated with a deduction of 20 trials, the blue colour was associated with a deduction of 150 trials, and the yellow colour was associated with a deduction of 10 trials, and the distinct element for one trial contained the colour yellow, then a correct selection in this trial resulted in 10 trials being deducted from the experiment. For that participant, a correct selection on a future trial where the distinct element contained the colour blue resulted in 150 trials deducted from the experiment, and so on. If participants clicked on one of the two incorrect elements, the stimulus disappeared, and a message appeared that said the participants had made an incorrect response (“Incorrect!”). If participants made no response within 2s of the stimulus being presented, the stimulus disappeared and was replaced with a message informing the participants to make a quicker response (“Be quicker with your response.”). Irrespective of
how the participant performed on a trial, the message displayed for 2s before the next trial commenced.

There were 240 trials before the next phase commenced. The distinct element contained each colour 80 trials each, in a pseudorandom sequence. The program recorded the number of trials in which the distinct element was selected when it contained each colour.

**Distractor Task.** In order to promote an overselectivity effect, a distractor task was presented while participants engaged in Phase 2. Before the start of Phase 2, participants were first presented with information about a distractor task. The following instructions were displayed on the screen:

*For the next part of the experiment, you will be presented with a 4x4 grid of squares for 30 seconds. Some of these grids will have objects. Try as best you can to remember the objects and their locations, as you will be required to recall these at a later point for a very large reward (4000 trials off the experiment), after performing a different task.*

*If anything is not clear, please ask the experimenter for help. Otherwise, if you understand the instructions, press the “Start” button to proceed to the next part of the experiment.*

The screen then displayed a four by four grid of squares (Figure 10). All of these squares were empty apart from four of these squares, which each contained an object, taken from the Snodgrass and Vanderwart (1980) stimulus set. Participants were given 30s to view the display of squares in order to encode the configuration of objects before they disappeared. Participants were required to recall the locations of these items at the termination of Phase 2. This was done by presenting the participants with the same grid of squares, but with no objects (such that all squares were empty), and asking participants to click on the squares that
had contained the objects. If participants correctly recalled all four locations of the previously displayed objects, the grid of squares disappeared from the screen, and a message appeared telling participants that they had performed the task correctly and that 4000 trials had been deducted (“Correct! 4000 trials off!”). If any of the squares that the participant selected were incorrect, the grid of squares disappeared and a message appeared informing participants that they were incorrect and had received no deduction of trials (“Incorrect! No trials off!”). The

![4x4 grid](image)

*Figure 10.* The 4x4 grid that was displayed with the objects that participants were required to remember.

participants then pressed a button to move to the next phase, which was Phase 3.

**Phase 2 – Training Phase.** This phase began with the following instructions displayed on the screen:
In Part Two, two groups of 3 Kanji characters will appear on the screen for a few seconds; one above, the other below. The same two groups appear each trial, but the characters within each group will be jumbled around each trial. One group will always be correct, and the other group will always be incorrect. You must click on the correct group before the two groups disappear. Whenever you select the correct group, the trials remaining will reduce by 30.

At first you must guess which group is correct, but after that it should be obvious which group is correct from then on.

If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button to proceed to the next part of the experiment.

For each trial of this phase, after a 2s pause, two compound stimuli, each comprised of three Kanji characters, displayed on the screen for 2s (Figure 11). One stimulus was displayed just above the centre of the screen, and the other stimulus was displayed just below the centre of the screen. Each stimulus was randomly comprised of three elements: each of which contained a unique Kanji character, and a unique colour of blue, red or yellow. No character appeared in both stimuli, such that there were six unique characters presented each trial. However, each element of each stimulus shared a colour with one element of the other stimulus.

The same stimuli were presented each trial. However, the positions of elements within each stimulus changed each trial (to insure that participants did not demonstrate more control for an element simply because of its position in the stimulus). In addition, the above-below position of the stimuli changed each trial (to control for any positional bias for high or low on
the screen). One of these stimuli - Stimulus A - was randomly allocated as correct across all trials of this phase, and the other stimulus - Stimulus B - was randomly allocated as incorrect across all trials of this phase. Participants had to select Stimulus A before both stimuli disappeared. If participants selected Stimulus A, both stimuli disappeared, and the participants received a message that said that they had performed the trial correctly and that 30 trials had been deducted (“Correct! 30 trials off!”). If participants selected Stimulus B, the stimuli also disappeared, but the message that appeared stated that the participant was incorrect (“Incorrect!”). If participants made no response within 2s of the stimuli being presented, the stimuli disappeared and a message appeared directing participants to make a faster response (“Be quicker with your response.”). For every trial, the message displayed for 2s, and then the next trial commenced. This procedure ran until participants made 10 successive correct responses. After this, participants recalled the locations of the objects in the distractor task. The program recorded the total number of trials that occurred for this

![Image 1](image1)

![Image 2](image2)

Figure 11. An example of the compound stimuli presented to a participant on a Phase 2 trial.

The higher stimulus was the correct training stimulus for this participant.
phase, and the total number of trials that the participant performed correctly.

**Phase 3 – Test Phase One.** The phase began with the following instructions displayed on the screen:

*In Part Three, two Kanji characters will appear on the screen for two seconds, one on the left and one on the right. One character will be one of the characters from the correct group in Part Two (that you have just completed). The other character comes from the incorrect group in Part Two. You must click the character from the previous “correct” group; whenever you do, 30 trials will be deducted from the total trials remaining. Different character from the two groups will be used each trial.*

*Unlike Parts One and Two, you WILL NOT be told if you were correct or not, and the total number of trials remaining will not appear on the screen. However, correct responses will still reduce the total trials remaining, even though you won’t be told.*

*If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button to proceed to the next part of the experiment.*

On each trial, after a 2s pause, participants were presented simultaneously with two characters on the left and right of the screen (Figure 12). One of these was an element from Stimulus A, and the other an element from Stimulus B. However, the colours that were contained in these elements in the previous phase were removed such that the elements presented were black-and-white characters. The position of the element from Stimulus A was randomized each trial to control for any positional bias. Participants were required to select the element from Stimulus A. Although participants were told to select the element from Stimulus A each trial, they were given no feedback on whether or not they had selected
correctly. When the element from Stimulus A or Stimulus B was selected, both elements immediately disappeared. The next trial began immediately. If participants made no response to either element, the elements disappeared, and a message displayed for 2s directing participants to select an element more quickly. (“Be quicker with your response.”).

For each trial, the program recorded the elements that had been presented, and the element that was selected. If no selection was made, this was recorded as no response for that trial. Each possible combination of elements was presented a maximum of five times, in a pseudorandom sequence, so forty-five trials took place in this phase before the next phase began.

**Phase 4 – Extinction Phase.** The following instructions were displayed on the screen at the start of this phase:

*In Part Four, two characters will appear each trial, one on the left and one on the right. One of these characters will be one you have already seen. This is the INCORRECT image. The other image will be NEW – it has not been used in Parts*
Two or Three. This will always be the CORRECT image. If you click this image, then you will reduce the total trials remaining by 30.

You WILL be told if you were correct or not, and the total number of trials remaining will be shown.

If anything is not clear, please ask the experimenter. Otherwise, if you understand the instructions, please press the “Start” button to proceed to the next part of the experiment.

Across all trials of this phase, after a 2s pause, the same two Kanji characters were presented simultaneously on the left and right of the screen (Figure 13). One of these characters was a novel character that had not been used in the two preceding phases. The other was the element from Stimulus A that contained the colour previously associated with the largest reward in Phase 1. Furthermore, this element in this phase contained the same colour that it

![Kanji Characters](image)

*Figure 13.* An example of the elements displayed on a Phase 4 trial for a participant. The element on the left was part of the correct training stimulus in Figure 11. The fact that this element is displayed indicates that the colour red was previously associated with the highest magnitude of reward for this participant.
had contained in Phase 2 (such that the salience that had previously been associated with the colour might be diminished in this phase).

The position of the two characters was randomised for each trial. If either character was selected, both characters disappeared and a message appeared on the screen for 2s. If the participant selected the novel element, the message said that they were correct and that 30 trials had been deducted from the experiment ("Correct! 30 trials off!"). The same was true if the element from Stimulus A was selected, with the exception that the message informed the participant that they had performed the trial incorrectly ("Incorrect!"). If no response was made to either character within 2s, the elements disappeared and a message that appeared for 2s told the participant to make a faster response ("Be quicker with your response"). This phase lasted until participants achieved ten successive responses to the correct element. The program recorded the total number of trials that occurred for this phase, and the total number of trials that the participant performed correctly.

Phase 5 – Test Phase Two. This phase was a repeat of Phase 3.

Results

Phase 1 – Visual Search Phase. To insure a greater likelihood that certain colours appeared more salient to participants, a criterion was set at of 80% correct for each of the colours that the distinct stimulus contained. Of the 26 participants, only one did not achieve criterion for all three colours, and this participant’s data were excluded from subsequent analyses.

Phase 2 – Training Phase. The participants learnt the discrimination slowly as a group, taking a mean of 42.50 (SD = 65.19) trials to reach criterion, with a range from 10 to 316 trials. Three participants (Participants 26, 43, and 46) could be classed as outliers, as they took an exceedingly large number of trials to reach criterion. When these participants’ data
were excluded, the mean trials to reach criterion for the group was only 24.22 ($SD = 13.48$); the rest of the group, therefore, learnt the discrimination moderately quickly.

**Phase 3 – Test Phase One.** In order to determine if the rewards previously associated with each colour in Phase 1 had any effect on which element was overselected in Phase 3, the proportion of trials participants selected the element when it contained the colour previously associated with the highest reward, the proportion of trials when it contained the colour previously associated with the second highest reward, and the proportion of trials when it contained the colour previously associated with the lowest reward, were calculated separately for each participant. Mean proportions were calculated across the group of participants to give a mean proportion of trials in which each element was selected (i.e., the mean proportion of trials performed correctly for the element that contained the colour previously associated with the highest reward, etc.). Figure 14 shows the results of this analysis. There was no effect of reward history. The elements that contained the colour previously associated with

![Figure 14](image)

**Figure 14.** Mean proportion of trials in which each element of Stimulus A was selected in Phase 3, in order of the magnitude of reward previously associated with the colour of each element.
the higher rewards were not selected on more trials than the elements that contained the
colours previously associated with lower rewards. The results of a Repeated-Measures One-
Way ANOVA were not significant \((F(2, 48) = 0.04, p = 0.96)\).

A One-Way Chi-Square test was performed to determine whether there was any
significant differences between the number of participants that selected most often the
element that contained the colour previously associated with the highest reward, the number
of participants who selected most often the element that contained the colour previously
associated with the second highest reward, or the number of participants who selected most
often the element that contained the colour previously associated with the third highest
reward. Evidence of an effect of reward history might be provided if a significantly greater
number of participants selected most often the element that contained the colour previously
associated with the highest reward. The results of the Chi-Square test were not significant
however \((X^2 (2, N = 31) = 0.45, p = 0.80)\), so the elements containing the colours previously
associated with the highest reward were not differentially selected.

The individual participant data was examined to ascertain whether any participants
demonstrated evidence of overselectivity unrelated to the rewards previously associated with
colours in Phase 1. Figure 15 shows the proportion of trials in which each element of
Stimulus A was selected for the individuals of the group that demonstrated overselectivity.
Fifteen of the twenty-five participants demonstrated some evidence of overselectivity,
showing a higher level of selectivity for either one or two elements. So, the lack of an effect
of reward history was not attributable to an absent overselectivity effect.

It may have been the case that an effect of reward history would only be evident for
those participants that actually demonstrated overselectivity. This was not the case. Figure 15
shows that participants were just as likely to overselect any of the elements, irrespective of
the reward previously associated with their colour. Of the participants that demonstrated
Figure 15. Proportion of trials in which each element of Stimulus A was selected in Phase 3, in order of the magnitude of reward previously associated with each element, for the 15 participants that demonstrated overselectivity in Phase 3.
overselectivity, only four demonstrated overselectivity for the element containing the colour previously associated with the highest reward (Element 1). Five, on the other hand, demonstrated overselectivity for the element containing the colour previously associated with the second highest reward (Element 2), and five for the element containing the colour previously associated with the lowest reward (Element 3). One participant showed joint overselectivity for elements containing the colours previously associated with the highest and lowest reward. A Chi-Square test conducted on these data found no differences between the number of participants that overselected the elements containing the colours previously associated with either the highest, second highest, or third highest reward. \( X^2(2, N = 16) = 0.13, p = 0.94 \).

**Phase 4 – Extinction Phase.** The number of trials taken to reach the criterion of ten successive responses was calculated for each participant. These were averaged across participants to produce a mean number of trials took to reach criterion for the group. This mean was 11.88 \((SD = 2.50)\) trials, with a range from 10 to 22 trials, indicating that participants learnt the discrimination quickly.

**Phase 5 – Test Phase Two.** Although there was no evidence of an effect of reward history, the data were analysed to determine if there was any evidence of emergence. These analyses were also performed to determine if the findings of Experiment 1 (i.e., increases in selectivity for elements when they had been selected more often than an element put in extinction, emergence for elements put in extinction, and increases in selectivity for certain elements without accompanying decreases in selectivity of other elements) could be replicated. The analyses focused on the 15 participants that demonstrated overselectivity in Phase 3. The proportion of trials in which these participants selected the same elements in Phases 3 and 5 was calculated in order to examine the effect of putting an element in extinction. Figure 16 shows these results.
Figure 16 shows that of the 15 participants that demonstrated overselectivity in Phase 3, only seven (Participants 29, 37, 39, 44, 48, 49, 50) showed evidence of overselectivity in Phase 5; that is, they showed a high level of selectivity for only one or two elements. Eight participants (Participants 26, 32, 33, 34, 35, 38, 41, 45) no longer showed evidence of overselectivity; that is, they showed high levels of selectivity for each of the three elements. This was the case even though six of these eight participants (Participants 26, 34, 35, 38, 41, 45) had underselected as many as two elements in Phase 3. Furthermore, five of these eight participants (Participants 32, 33, 35, 38, 45) that no longer showed evidence of overselectivity in Phase 5 performed perfectly, selecting all elements at a proportion of 1.0 in Phase 5. Thus, because they improved to show high selectivity for all elements, these participants showed increases in selectivity for certain elements that were not accompanied by decreases in selectivity of other elements. In fact, only seven of the fifteen participants (Participants 34, 37, 39, 44, 48, 49, 50) showed accompanying decreases in selectivity of elements when the selectivity of another element increased.

Thus, putting an arbitrary element in extinction in Phase 4 reduced overselectivity for many participants in Phase 5 despite the fact that the element put in extinction was not always the one that was most selected in Phase 3. In fact, of the eight participants that demonstrated no evidence of overselectivity in Phase 5, only three (Participants 26, 32, 34) had their most selected element put in extinction; four (Participants 35, 38, 41, 45) had their second most selected element put in extinction, and one (Participant 33) had their third most selected element put in extinction. Furthermore, all but one (Participant 34) of these eight participants that no longer demonstrated overselectivity in Phase 5 demonstrated the same or a higher level of selectivity in Phase 5 for the element that was put in extinction. Participant 44, a participant that still demonstrated evidence of overselectivity in Phase 5, also displayed improved performance for the element put in extinction. In fact, of the 15 participants
Figure 16. The proportion of trials in which the same elements were selected in Phases 3 and 5, in order of the magnitude of reward previously associated with the colour of each element, for the 15 participants that demonstrated overselectivity in Phase 3. Element 1 was the element put in extinction for all participants.
that demonstrated overselectivity in Phase 3, nine (29, 33, 35, 38, 41, 44, 45, 49, 50) demonstrated an increase in selectivity from Phase 3 to Phase 5 for the element put in extinction.

Five of the participants (Participants 33, 38, 41, 44, 45) that demonstrated overselectivity also displayed an increase in selectivity from Phase 3 to Phase 5 for an element that in Phase 3 had been selected more often than the element put in extinction; that is, putting an element in extinction resulted in increases in selectivity for other elements when those elements had been selected more often in Phase 3 than the element that was put under extinction.

Subsequent group analyses were also performed to examine the effect of putting differential elements (most selected, second most selected, or third most selected) in extinction, and to determine if groups findings were consistent with the findings of the individual data analyses. The data were separated into the subset of participants that had their most selected element put in extinction, the subset of participants that had their second most selected element put in extinction, and the subset of participants that had their third most selected put in extinction. Figure 17 shows the mean proportion of trials in which the same elements were selected in Phase 3 and Phase 5 for the three different subsets, in order of the magnitude of reward previously associated with the colour of each element.

The top panel of Figure 17 shows the results from the subset of participants that had their most selected element put in extinction. The element put in extinction showed a decrease in selectivity from Phase 3 to Phase 5. Selectivity for the two other elements increased after the extinction procedure, reflected by a higher proportion of trials in which
Figure 17. Mean proportion of trials in which the same elements were selected in Phase 3 and Phase 5, in order of the magnitude of reward previously associated with the colour of each element, for the individuals that had their most (top panel), second most (middle panel) or third most (bottom panel) selected element put in extinction. The element put in extinction was Element 1.
these elements were selected relative to Phase 3. Paired-Sample T-tests, however, showed that a significant difference in selectivity between Phases 3 and 5 was found only for Element 2 (previously underselected and not put in extinction) ($t(11) = 2.31, p < 0.05$). Thus, emergence was seen for only one of the previously underselected elements. This increase in selectivity was not accompanied by a significant decrease in selectivity of another element, consistent with the individual data analyses.

The results of the remaining subset analyses also produced results consistent with that of the individual participant analyses. For instance, the middle panel of Figure 17 shows the results from the subset of participants that had their second most selected element put in extinction. They showed increases in selectivity for Elements 2 and 3 when these elements had been selected more often than the element put in extinction (Element 1) in Phase 3. Furthermore, selectivity for the element put in extinction increased as well. Paired-Sample T-tests, however, found that only Element 3 showed a significant increase in selectivity from Phase 3 to Phase 5 ($t(7) = 2.44, p < 0.05$). Because this was the only element that showed a change in selectivity from Phase 3 to Phase 5, there was no accompanying significant decrease in selectivity for another element.

The bottom panel of Figure 17 shows results from the subset of participants that had their third most selected element put in extinction. They also showed an increase in selectivity for an element (Element 3) that had been overselected relative to the element put in extinction (Element 1). This subset also showed a large increase in selectivity for the element put in extinction. A Paired-Sample T-test also confirmed that this difference was significant ($t(4) = 3.00, p < 0.05$). Furthermore, while a small accompanying decrease in selectivity was seen for Element 2, this change in selectivity was not significant. Thus, the increase in selectivity in selectivity for Element 1 was not accompanied by a significant decrease in selectivity of another element.
Discussion

Experiment 2 examined whether participants would demonstrate greater control for certain elements of a compound stimulus by preliminarily associating colours contained within those elements with larger magnitudes of reward relative to the colours of other elements. An effect of reward history was expected because refinements made to the procedure of Experiment 1 would make it more likely. The results, however, still showed no effect of reward history; participants selected elements that contained colours previously associated with lower rewards at an equal level to elements that contained colours previously associated with higher rewards.

As in Experiment 1, which also showed no effect of reward history, many of the participants demonstrated an overselectivity effect in Experiment 2. In this sense, Experiment 2 replicated the results of previous studies that have demonstrated overselectivity in participants when also arranging a distractor task (e.g., Reed & Gibson, 2005; McHugh & Reed, 2007; Broomfield et al., 2010; Reed et al., 2012).

Experiment 2 also showed that the findings of previous studies (e.g., Broomfield et al., 2008; Broomfield et al., 2010; Reed et al., 2012), that have shown emergence of control of previously underselected elements when a previously overselected element is put in extinction, could be replicated. Broomfield et al. (2008; Experiment 1) arranged compound stimuli comprised of three elements, so in this respect their procedure was the most similar to Experiment 2. After they established an overselectivity effect in a first MTS phase and then put in extinction the most overselected element, they presented another MTS phase. The element that was overselected in the first MTS phase was selected significantly less in the second MTS phase, while the two elements that were selected the least in the first MTS phase were selected significantly more in the second MTS phase. In Experiment 2, a subset of participants had their most overselected element put in extinction, similar to Broomfield et
al.’s (2008; Experiment 1) study. These participants did not show significant differences in the level of selectivity between the first (Phase 3) and second test phases (Phase 5) for all elements. There was, however, a significant increase in the selectivity of one of the two previously underselected elements from the first to second test phase, indicating emergence of control for this element. Experiment 2, therefore, at least partially replicated the findings of Broomfield et al.’s (2008; Experiment 1) study. The reason that significant differences between the two phases was not seen for all three elements in Experiment 2 might be due to a lack of statistical power, given the small number of participants that fell into this subset.

Given that Experiment 2 anticipated that the element containing the colour previously associated with the highest reward would be overselected, it was prearranged that this element was put in extinction. Participants did not produce findings consistent with the reward history hypothesis, however, so it was often the case that the element put in extinction was one that the participants had selected the second or third most often in Phase 3. Thus, the effect of this could again be examined. Consistent with the findings of Experiment 1 increases in selectivity were observed for relatively overselected elements. Five of the fifteen participants that demonstrated overselectivity in the first test phase (Phase 3) showed increases in the level of selectivity from the first to the second test phase (Phase 5) for an element that in Phase 3 had been selected more often than the element later put in extinction. Furthermore, one of the subsets that had a previously underselected element put in extinction showed a significant increase in selectivity from the first to the second test phase for an element that had been overselected relative to the element put in extinction. Although an underselected element was put in extinction, it would still be expected to have salience, even if lower relative to the previously overselected element. Putting in extinction this relatively underselected element should function to increase the relative salience of other elements, which would result in other elements overshadowing this underselected element to an even
greater extent in a second test phase; these other elements would be selected more often in the second test phase relative to the first test phase as a result. This provides evidence for an overshadowing account in a manner different to any of the previous literature.

An overshadowing account cannot explain other findings from Experiment 2. Both subsets of participants that had a relatively underselected element (i.e., second or third most selected element) put in extinction showed significant increases in the selectivity of one element from the first (Phase 3) to the second (Phase 5) test phase without an accompanying decrease in the selectivity of another element. Furthermore, only seven of the fifteen participants that demonstrated increased selectivity for an element saw a decrease in the selectivity of another element or elements. Most past studies (e.g., Broomfield et al., 2008; Broomfield et al., 2010; Reed et al., 2012) that arranged an extinction procedure found that emergence for one element is typically offset by a reduction in selectivity of another element. The overshadowing account predicts that an increase in the selectivity of certain elements should occur when the salience of another element decreases as a result of an extinction procedure. In addition, examination of the individual data indicated that nine of the fifteen participants that demonstrated overselectivity in the first test phase showed an increase in selectivity from the first to the second test phase for the element put in extinction, consistent with the findings of Experiment 1. Only three of the participants demonstrated a decrease in selectivity from the first to the second test phase for the element that was put in extinction. There was also a substantial and significant increase from the first to the second test phase for the element that was put in extinction for the subset of participants who had their third most selected element put in extinction. These findings are inconsistent with previous research (Broomfield et al., 2008; Broomfield et al., 2010; Reed et al.) showing that control by an element put in extinction typically decreases from the first to the second test phase. The fact that control by an element put in extinction increased from the first to the second test phase is
also inconsistent with an overshadowing account. Selectivity for this element should decrease from the first to the second test phase, rather than increase, given that its salience should reduce on account of being put in extinction.

Given that Experiment 2 produced findings inconsistent with an overshadowing account, and that evidence used to support an overshadowing account has been used to dismiss an attentional account, perhaps an attentional account may have more support as a result of these findings. This suggests that an attentional account might explain the overselectivity effect in all populations, and not only for certain subsets as McHugh and Reed (2007) argue, making it a more parsimonious explanation of the effect.

The subset results should probably be treated with caution, given the small number of participants that fell into each of the different subsets (twelve had their most selected element put in extinction, eight had their second most selected element put in extinction, and five had their third most selected element put in extinction). A future study could induce an overselectivity effect, and then randomly allocate participants into groups that have either their most, second most, or least selected element put in extinction. If emergence for the element put in extinction was observed for all groups, this would provide better evidence against an overshadowing account of the overselectivity effect.

Decreases in selectivity for an element put in extinction may have also not been seen in Experiment 2 because of the design of the extinction phase (Phase 4). The novel element was black-and-white, and the training stimulus element put in extinction was the same colour as during training. Participants might have discriminated between the two elements on the basis of the colour of the novel element, rather than the Kanji character. Thus, the colour might have in effect been placed under extinction rather than the character. The degree of selectivity for the element put in extinction would, therefore, not have decreased when it reappeared in the second test phase (Phase 5), because the participant’s behaviour in the
extinction phase would have been under the control of the colour of the element, rather than the character. This would still not explain, however, why selectivity for the element put in extinction could in some instances be higher for the second test phase relative to the first (Phase 3). If participants were not under the control of the character in the extinction phase, increased exposure to this element should not increase the control by the character of the element.

If an overshadowing account offers no explanation of Experiment 2’s results, how can these findings be explained? Why might selectivity from a first (Phase 3) to a second test phase (Phase 5) increase for an element put in extinction? Previous research (Broomfield et al., 2008; Reed et al., 2012) has established that emergence is not attributable to merely running a second test phase. Participants exposed to two test phases without an extinction procedure show no significant changes between the two test phases. Previous research, however, has not ruled out the possibility that any emergence is attributable to merely running an extinction phase, irrespective of the element put in extinction (i.e., the most, second most, or least selected element). A closer examination of the Experiment 2’s data might provide an alternative answer to these questions. This data suggests that the degree of selectivity of an element in the first test phase appeared more predictive of whether selectivity for that element would decrease or increase in the second test phase than whether that element was put in extinction. Participants were likely to show decreases in selectivity for an element if that element had been selected to a high degree in the first test phase, irrespective of whether that element had been put in extinction (see Element 1 for Participants 34 and 39, Element 2 for Participant 48, and Element 3 for Participant 50 on Figure 16; and see Element 1 of the subset whose most selected element was put in extinction on the top panel of Figure 17). If an element was put in extinction, it generally only showed a decrease in selectivity from the first to the second test phase if had been maximally, or very highly
selected. This indicates that previous studies may have shown decreases in selectivity for elements put in extinction only because they were highly selected in a first test phase and because ceiling effects prevented them from being selected to a higher extent in a second test phase. This notion is further supported by the fact that participants showed a very consistent tendency to only show increases in selectivity for elements that were relatively underselected, with a few exceptions. Figure 16 shows that across individual participants, twenty-eight elements showed increases in selectivity, and only four of these elements (Elements 2 of Participants 38, 41, 45 and Element 3 of Participant 44 in Figure 16) were relatively overselected. Again, the level of selectivity of these elements was more predictive of whether these elements would show an increase in selectivity, rather than whether they were not put in extinction. This is because nine of these elements that showed increases were an element put in extinction. An overshadowing account predicts that selectivity for an element, and changes in its selectivity, depends on its salience and what has been put in extinction – not on the degree of selectivity of an element in a first test phase.

Perhaps a more satisfying explanation for why performance improved from the first (Phase 3) to the second test phase (Phase 5) for most elements, including the element put in extinction, is that further learning took place in the test phases. Some (e.g., Broomfield et al., 2010) might suggest that this is impossible, given that feedback (and reinforcement) was contingent only on selections made during training (Phase 2), and not in test phases. These arguments do not consider, however, that certain strategies implemented by the participants, particularly during the first test phase, might have helped them learn more about the correct and incorrect training stimuli, even if aspects of these stimuli were ignored or not salient in the training phase; that is, participants could learn whether an element was or was not part of a correct training stimulus, even when no feedback was provided. For example, consider a test phase trial that included a correct stimulus element that strongly controlled a participant’s
behaviour during training. The element presented simultaneously could not have been part of the correct training stimulus (as only one correct element was presented each trial). The participant could, therefore, learn that this element must have been part of the incorrect training stimulus. In a future trial, the participant could then learn that another element presented simultaneously with this incorrect element from the previous trial must therefore have been part of the correct stimulus. In this way, learning could take place during test trials. If this type of learning took place, then participants’ performance should have improved as a test phase progressed. The data from the first test phase was re-examined to see if there was evidence that this occurred. The difference between the number of correct trials for the first and last 18 trials of the first test phase was calculated for each participant. The differences were then averaged across participants, to produce a mean difference of 2.32 (SD = 2.66). A Paired-Sample T-Test showed that correct training stimulus elements were selected on significantly more trials in the last 18 trials compared to the first 18 trials ($t(24) = 4.37, p < 0.001$). Performance had improved from the start to the end of the first test phase, and so the participants must have learnt more about the training stimuli as the test phase progressed. Furthermore, this can explain why performance during the first test phase was worse than during the second test phase, as participants would have learnt more about the stimuli after the first test phase finished and before the second test phase begun.

The results of the above analysis could be attributable to participants being confused about what was required at the start of the first test phase. This would also cause more errors for the first 18 test trials relative to the last 18 (no response being made counted as an error). It is difficult to determine what errors were attributable to confusion of the participants, but no responses being made in the first trials would probably be an indication. The analysis was repeated but with the exclusion of data of the participants who made no response in the first three trials. A Paired-Sample T-Test again found that correct training stimulus elements were
selected on significantly more trials for the last 18 trials relative to the first 18 trials, despite this exclusion ($t(16) = 3.22, p < 0.01$). Thus, evidence of learning in test trials remained.

The results of Experiment 1 might provide evidence against the account that learning took place in the first test phase (Phase 3). If performance improved from the first to the second test phase (Phase 5) because participants learn more about stimuli in the first test phase, then participants in Experiment 1 should have shown less improvement from the first to the second test phase compared to the participants in Experiment 2. This is because training stimuli in Experiment 2 had twice the number of elements of Experiment 1; this would have made them harder to learn about in test phases. Every participant that showed overselectivity in the first test phase of Experiment 1, however, showed improved performance, and often to a large degree, whereas not every participant in Experiment 2 did. However, despite being exposed to a large number of elements, participants in Experiment 1 could have shown this improved performance because, as previously discussed, the presence of colours in test trials provided an extra aid to learn about the stimuli. This would also explain why the participants in Experiment 1 showed more likely improvement from the first to the second test phase compared to the participants in Experiment 2; learning about the stimuli with this colour strategy would arguably be easier than learning about the stimuli with the strategy that could have been employed in Experiment 2. It is difficult to determine that this is the reason why participants in Experiment 1 showed more improvement compared to the participants in Experiment 2. An analysis could not be done to determine if the participants in Experiment 1 had learnt about the stimuli in test trials, because data was not collected for every Experiment 1 test trial. Although, even if there was evidence of learning in test trials, this would not necessarily suggest that they were using the colour strategy to do so.
If learning can occur in the first test phase (Phases 3), then it might also provide a reason why such a small proportion of participants in the current study demonstrated the overselectivity effect in Phase 3. Of the 25 participants, only 15 demonstrated the effect, a proportion roughly equal to the proportion of participants that have demonstrated the overselectivity effect in previous studies. Broomfield et al. (2010), for instance, induced the overselectivity effect in 72 of 107 participants. The similarity in the proportion of participants that demonstrated the effect in their study and Experiment 2 is perhaps surprising, because the demands of Experiment 2’s task should have been more exhaustive in terms of working memory function compared to Broomfield et al.’s procedure. Broomfield et al. presented participants with two-element stimuli and a distractor task, whereas the current experiment presented participants with three-element stimuli and a distractor task. If overselectivity is induced by occupying working memory, why didn’t a greater proportion of participants demonstrate overselectivity in the current study relative to Broomfield et al.’s when demands associated with the task were higher? It may be because their distractor task was present for the totality of their study (the training, test, and extinction phases). In Experiment 2, the distractor task was only present in the training phase (Phase 2), so working memory function was free in the first test phase to implement strategies to learn more about the stimuli there. This freedom to implement strategies during the first test phase may have compensated for the increased number of elements that comprised the compound stimuli, and led to a smaller proportion of participants demonstrating the effect, roughly equal to the proportion that demonstrated the effect in Broomfield et al.’s study. A future experiment could test this idea by presenting a distractor task for only the training phase for one group while having the same distractor task present for both training and test phases for another group. If the group exposed to a distractor task for both training and test phases displayed less overselectivity, it might be because less working memory was available to learn more about the stimuli in the
first test phase. This would also provide evidence against a working memory account of the overselectivity effect, given that such an account would predict equal performance as long as a distractor task was only presented during training phases (a working memory account states that the overselectivity effect is induced when cognitive resources are occupied when responding to a compound stimulus).

The learning that took place in the first test phase (Phase 3) may have also prevented an effect of reward history. Participants during training (Phase 2) may have learnt and been initially controlled by the element containing the colour previously associated with the highest reward, and therefore selected this element at a high level in the test phase. However, this effect could have been obscured once participants learnt which other elements were part of the correct training stimulus during the first test phase, as this phase progressed. If so, the data should show that as the first test phase progressed, there would be greater improvements in selectivity for elements containing colours previously associated with lower rewards compared to elements containing colours previously associated with higher rewards. Examination of the data provided no evidence of this, however. Participants’ performance generally improved for all elements as the test phase progressed, and some participants showed low selectivity for the element containing the colour previously associated with the highest reward.

**General Discussion**

There was no effect of reward history in Experiments 1 or 2. The fact that learning may have taken place during test phases cannot explain this lack of effect. This suggests one of two things. It could suggest there was no effect of reward history because prior rewards really have no effect on determining which element will be overselected. Alternatively, it could suggest that there were some other aspect of the experiments’ procedures that did not allow for an effect of reward history to be induced. There are in fact several aspects that
could be responsible. First, although the number of trials that the distinct stimulus contained each colour in the visual search (Phase 1) of Experiment 2 was double that of Experiment 1 (80 rather than 40), this still may not have been sufficient for the colours associated with the higher rewards to appear more salient relative to other colours. In Anderson et al. (2011; Experiment 1), participants first selected a target stimulus that was illuminated that colour on 504 trials, much larger number than Experiments 1 or 2. It may be that more than 80 trials were needed for the associations to be learnt and for certain colours to appear more salient. The limited time that was available with each participant, however, did not allow for this.

An attentional account of the overselectivity effect offers a second explanation for the lack of effect of reward history. Participants may have differentially attended to the element that contained the colour previously associated with the highest reward in the training phase (Phase 2), but still produced the results of Experiments 1 and 2. How could this be the case? Although attention was captured by an element, this did not necessarily mean that attention was not also directed to other elements after this initial capture. For example, Anderson et al.’s (2011; Experiment 1) found that although a stimulus previously associated with a more frequent higher reward initially captured the attention of an individual, there were no significant differences in how accurately participants performed on the task when different distractors were used; merely that response times were slower when a distractor previously associated with more frequent higher reward was present in test trials. Participants still made accurate responses even if their attention, or behaviour, was initially controlled by a stimulus associated with a previous more frequent high reward. A future study might use eye-tracking to determine where the first fixations were directed when compound stimuli were first presented, and for the seconds after. However, even if eye gazes were solely captured by the element previously associated with the prior reward and then did not move to another
element, this would not necessarily preclude covert attention to other elements during this time. Such is the problem with relying on attentional accounts to explain such findings.

Third, removing the colours from the elements in test phases (Phases 3 and 5) in Experiment 2 may have prevented an effect of reward history. If the rewards previously associated with the colours of an element governed the extent to which that element would be selected, this may have caused problems when colours were removed from the elements in the first test phase. Colours were removed in test phases in Experiment 2 because participants could have used them as an aid to identify correct elements in test phases even when these elements had not controlled their responses during training (Phase 2). However, any larger salience that an element may have had – on account of the reward previously associated with its colour – may have been lost when the colour was no longer part of the element in test phases. Participants showing higher selectivity for the element containing the colour previously associated with the higher reward would be dependent on the high salience of that element remaining even when the colour was removed. Control would have had to shift from the colour of an element to the character. This may have been too much to expect. This problem could have been circumvented if entire elements, rather than colours that later became part of an element in a training phase, were associated with differential rewards in a visual search phase (Phase 1). For instance, in a visual search, participants could be rewarded for selecting the unique character each trial, similar to the design of Experiment 2. However, the reward given for correct selections would be contingent on the character that the participant selected, such that each character became associated with a reward of a differential magnitude. Later, a correct training stimulus could be comprised of the characters that had been associated with rewards in the preceding phase.

Fourth, any higher salience that elements containing colours previously associated with larger rewards might have had may have been attenuated because participants had to
click on the correct training stimulus in the training phase (Phase 2). During training, participants may have mistakenly determined that reward was dependent on selecting a particular element of the correct training stimulus, rather than any element of the stimulus, and repeatedly clicked on that element as a result. This element would, therefore, have been highly selected in the first test phase (Phases 3), not because it had been overselected, but because responding to that element in a training phase was effectively being reinforced.

Previous studies that have also used discrimination procedures to induce overselectivity (e.g., Broomfield et al, 2010; Reed et al., 2012) have presented participants with cards comprised of two-element stimuli, and reinforced participants for touching the card containing the reinforced stimulus, rather than a particular element on that card. This might prevent participants from being reinforced for selecting an element of the correct training stimulus in a training phase. In addition, participants had to navigate the mouse to the correct stimulus. The element of the correct training stimulus that the mouse landed on may not have been the element that appeared most salient to them on a given trial. As a result, participants may have been more likely to notice other elements of the correct training stimulus. This might have resulted in these participants selecting these elements more in a test phase than they otherwise would have, leading to more equal control across all elements, and a lower likelihood of seeing an effect of reward history. No data were collected to test these possibilities, however.

In future studies, key pressing responses (i.e., with the left and right arrow keys on a keyboard), rather than mouse clicks, might reduce the possibility that either of these things occurred.

Fifth, an effect of reward history may have been hindered because of the presence of an incorrect training stimulus in the training phase (Phase 2). It would be possible for participants to be controlled by an incorrect training stimulus, and make correct selections based on an element not being part of an incorrect stimulus, rather than an element being part
of a correct stimulus. This would be particularly likely if participants made incorrect responses for the first training trials, as this would mean that they had attended to and been controlled by elements of the incorrect training stimulus. If a participant was controlled by elements of the incorrect training stimulus, this would mean that in the first test phase (Phase 3) they would select correct stimulus elements that were paired with the incorrect stimulus elements that had controlled their behaviour in the training phase. Because any correct stimulus element could be paired with the incorrect stimulus elements that controlled the participant’s behaviour, this would mean that the group of participants would be just as likely to overselect any element of the correct training stimulus, rather than systematically overselect the element that contained the colour previously associated with the largest reward. Therefore, an effect of reward history would not be observed. To prevent the possibility that participants were controlled by the incorrect training stimulus, rather than the correct training stimulus, only one training stimulus could be presented in the training phase. Then, elements from the stimulus, and novel elements, could be presented in isolation in successive trials of a Go/No-go test procedure. Participants would be required to select an element if it had been part of the correct training stimulus and not select it if it had not been.

The use of a Go/No-go procedure could also prevent the possibility that participants do not show an effect of reward history because of learning that takes place in the first test phase (Phases 3). Participants would be prevented from learning about the stimuli in the test phase because the strategy for doing so requires two elements to be presented each test trial (a participant can only learn that an element was part of a correct stimulus during a test phase if an element that the participant has been able to determine is incorrect is presented with it simultaneously). Thus, participants would only be able to show high selectivity for elements that had controlled their behaviour in the training phase, which might be the elements previously associated with higher rewards. Of course, such a procedure would also require
that participants be told that they would receive punishment of more trials to perform if an incorrect response was made. This would be necessary in order to prevent the participant selecting every element each trial irrespective of whether it had or had not controlled their behaviour during training.

Although no effect of reward history was observed in both Experiments 1 and 2, this does not necessarily suggest that an effect of reward history is not possible. Aspects of the experiments’ designs may not have allowed for this effect to be induced. To prevent this possibility in a future study it was suggested that only one training stimulus should be presented, and a Go/No-go test follow in which only one element is presented each trial. It was also suggested that whole elements rather than features of those elements be previously associated with particular rewards, and over a much larger number of trials to give the highest likelihood that certain elements appear more salient. If no effect of reward history is produced, this would probably suggest that elements of a compound stimulus are not selected on the basis of reward histories. An observed effect, however, would not necessarily suggest elements previously associated with larger rewards overshadow elements previously associated with smaller rewards. This is because of findings in both of the experiments that provide evidence inconsistent with an overshadowing account. However, more studies need to be done to ascertain that these findings (e.g., emergence for underselected elements put in extinction) were not attributable to some artefact of the current designs.
References


Reed, P., Broomfield, L., McHugh, L., McCausland, A., & Leader, G. (2009). Extinction of over-selected stimuli causes emergence of under-selected cues in higher functioning


Appendix A: Participant Information Sheet

*Discrimination and Stimulus Control*

INFORMATION SHEET FOR PARTICIPANTS or PARENTS / GUARDIANS ETC.

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

**What is the Aim of the Project?**

In this project, our aims are to determine which features of stimuli participants are most likely to demonstrate control for, and the variables that affect this performance. This project is being undertaken as part of the requirements for Luca Blumhardt’s Masters in Science.

**What Types of Participants are being sought?**

We are seeking approximately 90 students, within the ages of 17 – 55, for this study whom we are recruiting via the department’s experimental participation method where undergraduates must take part in postgraduate research for course credit. Participants will have access to the results of their research, if requested, at the termination of the research. Participation in this study will enable further insight into the overselectivity phenomenon.

**What will Participants be asked to do?**

Should you agree to take part in this project, you will be asked to perform a series of choice tasks on a computer program that should take approximately 30 minutes in total. However, accurate performance will be rewarded with trials off the experiment, meaning that the more accurately you perform, the sooner you can leave. There are no known harm or risk that should occur as a result of agreeing to take part in this experiment. Please be aware that you may decide not to take part in the project without any disadvantage to yourself.

**What Data or Information will be collected and what use will be made of it?**

The data we will collect will be the total number of trials you undertake in each phase of the experiment, and the number of these trials in which you perform correctly, along with the types of stimuli that you tend to perform most accurately on. All of this data will be recorded automatically on the software you will perform the task on, and will be collected for the purpose of analysis such that
we can verify our hypotheses. Your personal results and the results of the study will be accessible to you approximately six months after your participation, should you wish to request it. No personal information will be collected and your participation will not be known to others.

The only individuals who will have access to the data are the researcher and his supervisor. This data will be stored securely in such a way that only those just mentioned will be able to gain access to it. Data obtained as a result of the research will be retained for at least 5 years in secure storage. Any personal information held on the participants may be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but anonymity will be preserved.

Can Participants change their mind and withdraw from the project?

You may withdraw from participation in the project at any time during the course of the experiment without any disadvantage to yourself.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either:-

Luca Blumhardt and Dr. Brent Alsop
Department of Psychology Department of Psychology
University Telephone Number: 479 7615. University Telephone Number: 479 7615
Email: blulu933@student.otago.ac.nz Email: balsop@psy.otago.ac.nz

This study has been approved by the Department stated above. However, if you have any concerns about the ethical conduct of the research you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph 03 479-8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.
Appendix B: Consent Form

Memory and Stimulus Control
CONSENT FORM FOR
PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-
1. My participation in the project is entirely voluntary;
2. I am free to withdraw from the project at any time without any disadvantage;
3. Personal identifying information will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;
4. No discomfort should come as a result of participation in this study;
5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

.............................................................................
(Signature of participant) (Date)

.............................................................................
(Printed Name)

[The advertisement which will be used to recruit participants should be attached to the application for ethical approval. This template can be used to develop the advertisement. Please ensure the standard of the written material is of the highest quality, with correct spelling and grammar. You may wish to include an image to increase your advertisement’s appeal.

Please note: The University’s Marketing and Communications Division encourages researchers to contact them regarding the printing of advertisements once the application and the advertisement are approved by the Human Ethics Committee. Please contact: Ryan Helliwell, Advertising Co-ordinator, Marketing Services, Phone: 03 479 8463 Email: ryan.helliwell@otago.ac.nz]