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BRIEF REPORT

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Confirming the existence of a within-array novel pop-out effect using a novel procedure

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ABSTRACT
The within-array novel pop-out effect occurs when a novel item within a display is more quickly and accurately detected than familiar items. This study strengthens the evidence for this effect by using a novel procedure that controls for previously unaddressed confounds. Two experiments presented participants with item arrays that were either all familiar, all novel, or a mix of familiar and novel items. Items were made novel or familiar through a pre-exposure phase, but this phase was made irrelevant to the test demands. The results showed a robust novel pop-out effect, even under conditions of minimal stimulus similarity, no memory load, and using displays that were not always task relevant. These findings provide strong support for the existence of the within-array novel pop-out effect, and they highlight the importance of careful experimental design in demonstrating this phenomenon.

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Novel pop-out; familiar sink-in; attention

Control of behaviour by unexpected or novel stimuli has been extensively researched across many paradigms (Diliberto et al., 1998; Johnston et al., 1990; Lubow & Kaplan, 1997; O'Donnell et al., 2021; Pearce & Hall, 1980; Vatterott & Vecera, 2015; Yang et al., 2009). The "novel pop-out" effect has contributed to this debate and refers to capture of responding by unexpected/unfamiliar stimuli presented along with familiar stimuli (Brascamp et al., 2011; Johnston et al., 1990; O'Donnell et al., 2021). This effect has implications for theories concerning bottom-up stimulus-driven and conceptual top-down theories (Christie & Klein, 1996; Diliberto et al., 1998; Horstmann, 2007; Johnston & Hawley, 1994; Vatterott & Vecera, 2015), and latent inhibition (Lubow & Kaplan, 1997; Pearce & Hall, 1980; Reed et al., 2008), but has also been employed to investigate real-world effects (Sauter et al., 2020), individual differences (Christie, 2006) and processing differences across clinical disorders (Leonard et al., 2020; Lubow et al., 1999; Lubow et al., 2000). Despite an assumed importance (Brascamp et al., 2011; O'Donnell et al., 2021; Vatterott & Vecera, 2015), challenges have been made to novel pop-out findings (Christie & Klein, 1996; Diliberto et al., 1998), which make theoretical interpretations and applied implications ambiguous (Horstmann, 2007; Johnston & Hawley, 1994; Vatterott & Vecera, 2015; Yang et al., 2009). This suggests that the original findings need re-visiting to establish their robustness and potential boundary conditions.

Typically, pop-out effects are demonstrated in tasks briefly presenting four-word stimulus-arrays and subsequently probing for the location of a particular word from that display (Diliberto et al., 1998; Johnston et al., 1990; Yang et al., 2009). Three effects have been reported when using such procedures: (i) location accuracy is greatest in all-familiar and lowest in all-novel arrays; (ii) when a single novel item appears in an otherwise familiar field (a mixed-array), accuracy is highest for the single novel item compared to items in an all-familiar array ("between-arrays novel pop-out"), and familiar items in the mixed-array ("within-array novel pop-out"); and (iii) localisation for familiar items in a mixed-array is lower than for familiar items in an all-familiar array ("between-array familiar sink-in").

It is important to note that between-array effects could be explained through task difficulty rather than attention capture (Christie & Klein, 1995; Diliberto et al., 1998; Johnston & Hawley, 1994). If familiar items are easier to process than novel items, then processing demands will increase with the number of novel items in the array (Christie & Klein, 1995). Thus, relative to all-

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familiar arrays, the localisation of a familiar item from mixed-arrays is more difficult and the localisation of a novel item is easier (Lubow et al., 2000). However, this argument cannot accommodate within-array effects and, thus, these effects are central to the demonstration of novel pop-out.

Unfortunately, within-array novel pop-out can be elusive, and, where found, there are potential experimental flaws (Christie & Klein, 1995; Johnston et al., 1990). In many within-array pop-out studies, novel items have an advantage as they are probed (tested for) more often than familiar items relative to their rates of presentation (Christie & Klein, 1995; Lubow et al., 2000). When tested proportionally to the number of times and items presented during exposure (e.g. in a 3:1 familiar: novel array, novel items are tested on 25% of probes), within-array effects are less often observed (Hawley et al., 1994; Hawley et al., 1994; Johnston & Schwarting, 1997). Nevertheless, using proportional testing, some procedures have found novel pop-out effects (e.g. Diliberto et al., 1998; McCarthy & Reed, 2023). Thus, given the mixed evidence, it seems important to further explore their reliability.

Additionally, in the original paradigm, every array presented was probed for item location, making all arrays relevant to the task (Johnston et al., 1990). This would encourage extensive sampling of each array, enhancing array elaboration and improving subsequent target matching. This would boost performance for familiar words, producing an advantage for all-familiar displays, and masking within-array novel pop-out through enhancement of familiar-word performance. McCarthy and Reed (2023) utilised a procedure addressing this issue, and noted a within-array pop-out, but found the all-familiar advantage was abolished. In this procedure, participants were pre-exposed, between five and – eight times, to a spatial array of four words taken from a set that they had seen many times (i.e. they were familiar). Each word was presented in a particular location in the array. Following a varied number of repetitions of pre-exposure displays, participants were presented with an orienting display, composed of three of the familiar words from the pre-exposure part of the trial, and one novel word. After this, participants were presented with the same word in four different locations (this could be any of the four words from the orienting display), and they were asked to identify its location in the preceding orienting display. Testing was proportional to the presentation, and not all of the initial arrays were probed (meaning that they were not constantly relevant). Nevertheless, participants found it easier to correctly identify the location of the word when it was novel.

There are two further problems with designs used in previous demonstrations of pop-out. First, these designs are often dependent on consciously memorising a location, and memory load could exert influence beyond automatic attention processes (Christie & Klein, 1995). Johnston et al. (1999) had participants actively remember locations of words in arrays, and later select the location in which the probed word had been presented. Thus the probe test was reliant on information from the arrays that was no longer present (Christie & Klein, 1995). However, Diliberto et al. (2000) used a brightness localisation task that did not require such a memory component, and obtained a smaller, but significant novel pop-out effect. In this task, participants were presented with an array of four (three drawn from a familiar set used repeatedly during the study and one which was novel). One of the four words was made brighter than the other three by varying its' intensity level. Following offset of the words, participants were asked to identify the location at which the brighter words were presented (which does not require differential recollection of novel versus familiar word identity). This was done more accurately when the word that was brighter was also novel. However, the arrays were always probed, making them constantly relevant.

Second, several studies have demonstrated that novelty per se is not necessary for a pop-out (Diliberto et al., 1998). In many studies, novelty is a relative term within the context of the experiment, as all stimuli were words familiar to participants (Diliberto et al., 1998; Hawley et al., 1994; Johnston et al., 1990; 1993; McCarthy & Reed, 2023). Due to possible similarities between the word stimuli used, such as their perceptual attributes, or the semantic content (perhaps referring to items from similar categories), the size of novel pop-out may be underestimated, as it may be more difficult to detect stimulus change in probe trials when the novel stimulus replaces a stimulus to which it is highly similar.

Thus the present series of studies had three aims: to develop a paradigm which could minimise stimulus similarity; employ probe tests lacking an active or conscious memory component; and directly vary the relevance of the displays to the task. Such a procedure allows testing many aspects of attention, and a stronger test of the empirical validity of novel pop-out.

Experiment 1

The present task involved identifying target stimuli (words) located in one of four locations in a visual array. This procedure attempted to minimise potential similarity between word stimuli by associating each word in the array with a unique colour. The colour stimuli were presented on four square blocks on which words were written (Tsakanikos & Reed, 2005). The colour-cueing effect for the words was achieved by expanding the spatial resolution of the display to give the impression of the blocks approaching from a distance (McCarthy & Reed, 2023). At low spatial resolution, the objects appeared distant, and only their colour but not the associated word could be identified. As the spatial resolution increased, the objects appeared to approach, and the participants could identify the words. Thus the colour served as a cue for potential word locations, and attention to the colour, which was clear before the word, could facilitate (or hinder) subsequent word recognition. As the task involved word recognition concurrent with the presentation of the test, the present procedure avoided the need for memorisation of the target location.

The possible role of sustained attention in previous findings was addressed by varying the relevance of the colours in the arrays. The relevance of colours could be manipulated through a pre-exposure display serving to produce familiarity or novelty of the colours on which a word would be displayed during a test. On such pre-exposure displays, the colours but not words would be presented. Hence, there was no explicit requirement for participants to pay attention to every trial, making the pre-exposure displays irrelevant for word naming.

Four conditions were examined in the present experiment. In a one-novel condition, three of the four colour cues used on the test displays were familiar, having been presented during pre-exposure displays; and one cue was novel, not having been presented during these pre-exposure displays. A bias (novel pop-out) was expected to favour words presented on the lone novel colour cue. In the all-familiar and all-novel conditions, all colours had equivalent pre-exposure histories to one another on any given trial; either having all been pre-exposed (all-familiar), or none having been pre-exposed (all novel). In these cases, no selection bias would necessarily be expected. Finally, in a one-familiar condition, the lone familiar cue was presented with three novel cues. The pattern of data predicted for this condition is unclear. Diliberto et al. (2000; Experiment 3) found an advantage for the one familiar item, using a brightness localisation task, although it should be noted that the paradigm (a brightness localisation task) is vastly different to the current procedure. Likewise, the familiar stimulus in this array, being different from the other three cues by virtue of its lack of novelty (Macphail & Reilly, 1989), may produce a category pop-out effect. In contrast, the repetition of this cue might produce worse performance, resulting in sink-in or latent inhibition (Lubow & Kaplan, 1997; Reed, 1995). Alternatively, these two effects could act in opposition, producing no effect.

Method

Participants

120 participants (82 female, 38 male) were recruited. All participants reported that they were not colour blind. They had a mean age of 20 ($SD \pm 1.6$; range = 18–24) years. All were unpaid volunteers, who were naive to the purpose of the experiment. G-Power calculations suggested that, with a medium effect size ($f' = .25$), a $p < .05$ rejection criterion, and 95% power, 73 participants would be required for a four-group repeated-measures analysis of variance (ANOVA). Ethical approval was given by the Psychology Department Ethics Committee of the University.

Apparatus

A stimulus pool of 288 five-letter, concrete nouns was compiled, from which stimuli were randomly selected for each trial of the experiment. Once used a word was not represented for a particular participant. The frequency of these words was assessed using the Kucera–Francis scales (Kucera & Francis, 1967); their imaginability was measured using a 1–7 scale (Gilhooly & Logie, 1980), where 1 = great difficultly arousing image and 7 = arousing images most easily; and their concreteness measured using a 1–5 scale (Brysbaert et al., 2014), where 1 = very abstract and 5 = very concrete. The means for these measures for word sets were: frequency = 88.32 ± 73.48; imaginability = 5.54 ± 1.07 and concreteness = 4.04 ± 1.22.

The displays were presented to the participants as a series of short, animated video sequences. All animations were constructed using a three-dimensional model package and were presented with multimedia animation player. Each animation depicted four square blocks, which were identical in size to one another. Different colours could be used to fill the blocks; on the HSB (hue, saturation, brightness) scale there was constant saturation (100%) and brightness (75%). Each block contained a string of five letters. This string could either a word or a non-word. Participants had to name the words when they saw them, which was recorded on the computer's microphone.

The block arrays were viewed from a position that moved along an axis perpendicular to the items and passing through the centre of the four-block configuration. Each animation was composed of 30 frames, and were each presented at a rate of 20 frames per second, meaning that each trial lasted for 1500 ms. The animation produces an impression of motion, such that the blocks appear, perceptually, to loom from a distance towards the participant, reach maximum size after about 750 ms, and then recede back into the distance. At their largest presentation, each word in an array subtended a visual angle of 1.9° horizontally, and a .64° vertically, from a viewing distance of 50 cm. This point was reached after 750 ms from the start of the trial. The entire array subtended an angle of 5.1° horizontally and 4.5° vertically. The words became visible at different points in this process for different participants, depending on the participant's visual acuity, but, on average, they were clearly visible after 500 ms, and until 1000 ms, after the trial started.

Procedure

Participants were tested individually in small laboratory cubicles, each containing a desk, chair, and computer with a monitor.

All participants were each exposed to four conditions: one-novel, all-familiar, one-familiar and all-novel (see Figure 1). The four conditions were presented in a random order across the participants. For each of the four conditions, there were 20 trials (making 80 trials in total). Each trial comprised six animated displays: a sequence of five repeating identical pre-exposure (PX-T) displays, followed by a single orienting (OR-T) display. Each display lasted for 1.5 s with an .8-s interval between each display. Thus each trial lasted 12 s, each condition lasted 240 s, and the whole experiment lasted 960 s.

In each trial, participants were presented with four coloured blocks. Each block could either have a word or a non-word of random letter strings in them. The words presented were different on each trial and were chosen randomly from the pool of words (with the proviso that once used, they were not resampled). The random letter strings were different on each block of each trial and were generated randomly for each display. In each of the different conditions, the familiarity or novelty of the colours appearing in the orienting (OR-T) display part of each trial was established during the immediately previous pre-exposure (PX-T) display part of that trial. During PX-T displays, no words were ever presented (just non-words in each block). The orienting (OR-T) display, again, had four coloured blocks, which could be the same or different colours from those in the preceding PX-T displays, depending on the condition. During the OR-T part of the trial, one block was always red. Two of the blocks always had words written in them. The red block always had a word, and the other word was located on one of the other colours (randomly chosen from trial to trial). The remaining two blocks contained non-word letter strings. During a trial (i.e. a sequence of five PX-T and one OR-T displays), the colours always appeared in the same spatial location, but this spatial location altered randomly from trial to trial.

One-novel condition: The top panel of Figure 1 displays the one-novel condition. On each of the 20 trials there were five identical PX-T displays. On each PX-T display there were four differently coloured blocks, each presented at the same location during a trial (but at different locations from trial to trial, determined randomly). Each block contained a different non-word random letter string. On the one OR-T display for each trial, there were four differently coloured blocks; three of the blocks were the same colour in the same location as on the previous 5 PT-X displays; whereas the other block was changed to the colour red, which had previously not been presented in the pre-exposure display. Two of the blocks on the OR-T display contained words (always the novel red one and a randomly selected colour), and two contained non-word random letter strings.

All-familiar condition is shown in the second panel of Figure 1. Each trial in the conditions had 5 PX-T displays and 1 OR-T display. In each of the 5 PX-=T displays for each trial, there were four different coloured blocks (one was always red), each containing non-words. On each trial, the blocks were in the same spatial location for each of the 5 PX-T displays, but this spatial location changed from trial-to-trial. On the OR-T display for each trial, the block colours (and their spatial location) remained consistent from the preceding 5 PX-T displays. The red block always contained a word, as did one of the other coloured blocks (random from trial to trial). The other two blocks contained a non-word random letter string.

One-familiar condition is shown in the third panel of Figure 1. In each of the 20 trials, the 4 blocks in the 5 PX-T displays were all red, and all had a different non-word letter string. For the OR-T display on each trial, one block was red (with a word) and the other three had different colours (one with a word and the other two with a letter string).

All-novel condition (bottom panel of Figure 1) displayed 4 white blocks in each of the PX-T displays. It was thought that presenting white blocks may limit any generalisation between the PX-T display and subsequent colours in the OR-T displays; for example, presenting in the PX-T displays a different colour to any of those used in the OR-T displays may have led to a greater similarity between the putatively different PX-T

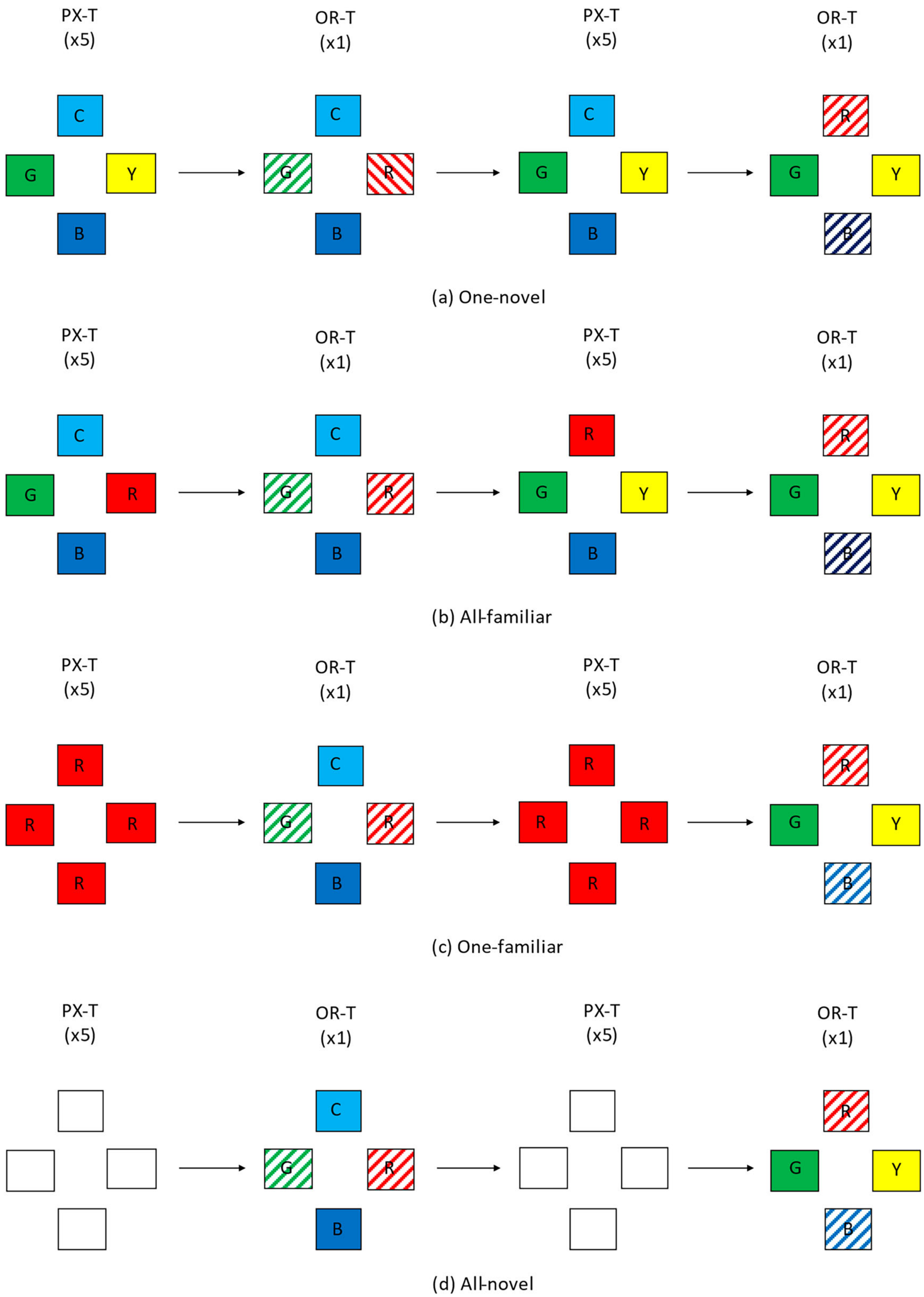

Figure 1. Design for Experiment 1: PX-T, pre-exposure trial; OR-T, orienting trial; R, red; B, blue; Y, yellow; C, cyan; G, green; solid squares, non-word; diagonal stripes, word. (a) One-novel trials; (b) all-familiar trials; (c) one-familiar trials; (d) all-novel trials.

colour and one of the OR-T display colours, each block with a different non-word letter string. For the OR-T display on each trial, each block had a different colour. One block was always red with a word, one of the other colours had a word, and the other two blocks had non-word letter strings.

Participants were informed that their task was to look for words in the displays. When they detected a word, they had to name it out loud as soon as they had seen it. Participants were not told how many words the display contained, nor that there were PX-T and OR-T parts to each trial. The critical measure during the OR-T displays was which of the two words the participant named first.

Results and discussion

To investigate selection bias between word blocks, a bias index (BI) was calculated as the difference between the number of words selected on the red block and the number selected that were not on the red block. This difference was then scaled to give a number between +1 and −1. For example, if a participant selected the red block on all 20 trials, their index would be: BI = (20–0)/20 = 1. If only 10 words were selected during 20 test trials, and these were never from the red block, then BI = (0–10)/20 = −.50. If 15 words were identified, and none of them came from the red block, then BI = (0–15)/20 = −.75 Thus, without bias, the mean BI was expected to be 0; but, with a bias towards red, then BI will deviate from 0 towards either +1 (always red) to −1 (never red). All participants showed the evidence of following the instruction. The mean number of words identified correctly from the blocks (as opposed to calling out words that were not there or failing to identify any word) was over 90% of trials, with a range of 85–100%.

The BI for the red block was calculated for each participant, for each condition. Figure 2 presents the mean BI for the red block in each condition. This reveals clear selection bias towards the red block in the one-novel condition. This is attributable to novel pop-out, as the red colour was the only novel colour in the orienting test trial, and there was no red bias when the colours were all-familiar. In the remaining two conditions, no selection bias towards red was observed. When the red block was the one-familiar colour, if anything, there was a bias away from the red block, representing familiar sink-in (the opposite effect that noted by Diliberto et al., 2000; Experiment 3). In the all-novel condition, there was a slight numerical bias towards the red block, which may indicate a slight preference for the red block, when all colours are novel.

To confirm this description, a repeated-measures ANOVA was conducted on the BI, with the four conditions as a between-subject factor. This revealed a significant effect of condition, $F(3,357) = 167.26$, $p < .001$, $\eta_p^2 = .584$[*95%CI* = .520:.632]. Paired t-tests conducted between conditions, with Bonferroni correction ($p = .05/6 = .008$), revealed all pairwise comparisons were significant, all $ts > 3.00$, $ps < .001$, smallest $d = .297$ [.11:.480], except for the all-novel versus all-familiar comparison, $t < 1$, $d = .010$[−.169: .189]. Comparisons between the BI and zero using paired t-tests (Bonferroni correction: $p = .05/4 = .0125$) revealed that the one-novel condition had a higher BI than zero, $t(119) = 25.61$, $p < .001$, $d = 2.339$ [1.991: 2.684], but none of the comparisons with zero for the other conditions were significant, smallest $p = .013$, largest $d = .229$ [.047: .410].

Within-array novel pop-out was generated using this procedure, which is consistent with previous experiments (Johnston et al., 1990; 1993). Participants tended to identify the word on the red block, when the red block was the only novel item, more often than words on familiar items. Although none of the other conditions produced significant pop-out, some caution should be applied, as there seemed to be a bias towards identifying the word on the red block when all colours in the array were novel (although this effect was not significant).

Experiment 2

Experiment 2 replicated Experiment 1 but used colours other than red for targets. The design and displays were identical to those in Experiment 1, except that displays were created for all possible combinations of the set of five colours; for example, if yellow were the novel cue, then the pre-exposure display contained blue, green, red and cyan.

Method

Participants and apparatus

There were 120 participants (79 female, 41 male) recruited, with a mean age of 21.35 (± 3.04; range = 18–28) years. All were unpaid volunteers and were naive as to the purpose of the experiment. The apparatus was as described in Experiment 1.

Procedure

The participants each experienced the four conditions: one-novel, all-familiar, one-familiar and all-novel. In each condition, the participants were each presented with a total of 50 trials of the types described in Experiment 1. Each trial comprised five pre-exposure (PX-T) displays, followed by a single orienting (OR-T) display. During the 50 trials in each condition, each of the five colours was tested as the probe colour ten times. All of the other details of the procedure were as described in Experiment 1.

Results and discussion

All participants showed the evidence of following the instruction. The mean number of words identified correctly from the blocks (as opposed to calling out words

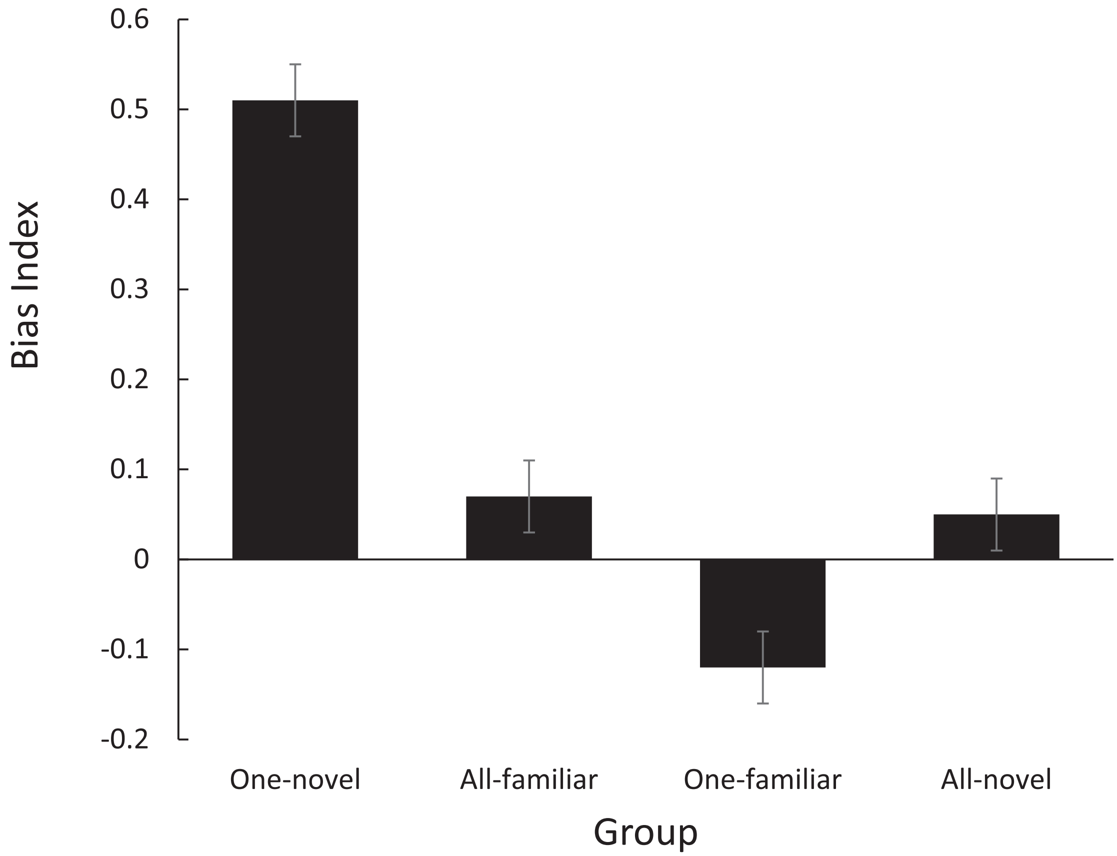

Figure 2. Results from Experiment 1: mean bias index for all four conditions. Error bars, 95% confidence limits.

that were not there or failing to identify any word) was over 85% of trials, with a range of 80–100%.

Figure 3 shows the mean BI for each condition and reveals within-array pop-out for the one-novel condition. There was an effect in the direction of familiar sink-in, but neither of the other two conditions produced any bias. This suggests within-array novel pop-out can be generated, even when red is not used as the target colour. A two-factor repeated-measures ANOVA (condition × colour) revealed a significant main effect of condition, $F(3,357) = 254.36$, $p < .001$, $\eta_p^2 = .681$ [.629:.719], but not of colour, $F(4,476) = 1.91$, $p = .108$, $\eta_p^2 = .0158$[.000:.037], nor was there a significant interaction, $F(12,1428) = 1.28$, $p = .222$, $\eta_p^2 = .011$[.000:.014]. Paired *t*-tests conducted between the conditions (Bonferroni correction: $p = .05/6 = .008$) revealed all pairwise comparisons were significant, all $ts > 11.00$, $ps < .001$, smallest $d = 1.013$[.791:1.232], except for the all-novel versus all-familiar comparison, $t < 1$, $d = .008$[-.187:.171]. Comparisons between the BI and zero (Bonferroni correction: $p = .05/4 = .0125$) revealed a significant difference for the one-novel condition, $t(119) = 18.33$, $p < .001$, $d = 1.674$ [1.394:1.950], and one-familiar condition, $t(119) = 18.64$, $p < .001$, $d = 1.702$[1.420:1.981], but not for the other two conditions, $ps > .05$.

Table 1 presents the mean BI for each individual colour as a target. While red produced a stronger numerical novel pop-out effect, and a weaker numerical familiar sink-in effect, the general pattern of the colours was the same as one another. These data suggest that red does attract attention readily, although this bias is exaggerated when red is presented in a familiar context and is eliminated with repetition.

Overall, Experiment 2 replicated the within-array novel pop-out effect, noted in Experiment 1. Experiment 2 also showed a familiar sink-in effect for the one familiar condition. This is the opposite to that shown by Diliberto et al. (2000), who noted a novel pop-out effect with this condition. The difference could be due to the different paradigms used. However, the fact that this effect was not found statistically in the current Experiment 1 suggests some care is needed in interpreting these results. Another issue, that is worth comment, is that the BI values were somewhat smaller in Experiment 2 than in Experiment 1. This may reflect an inherent bias towards red, although even when examined separately the BI for red in Experiment 2 was lower than that seen in Experiment 1. Alternatively, the lower BI values in Experiment 2 may reflect some habituation or

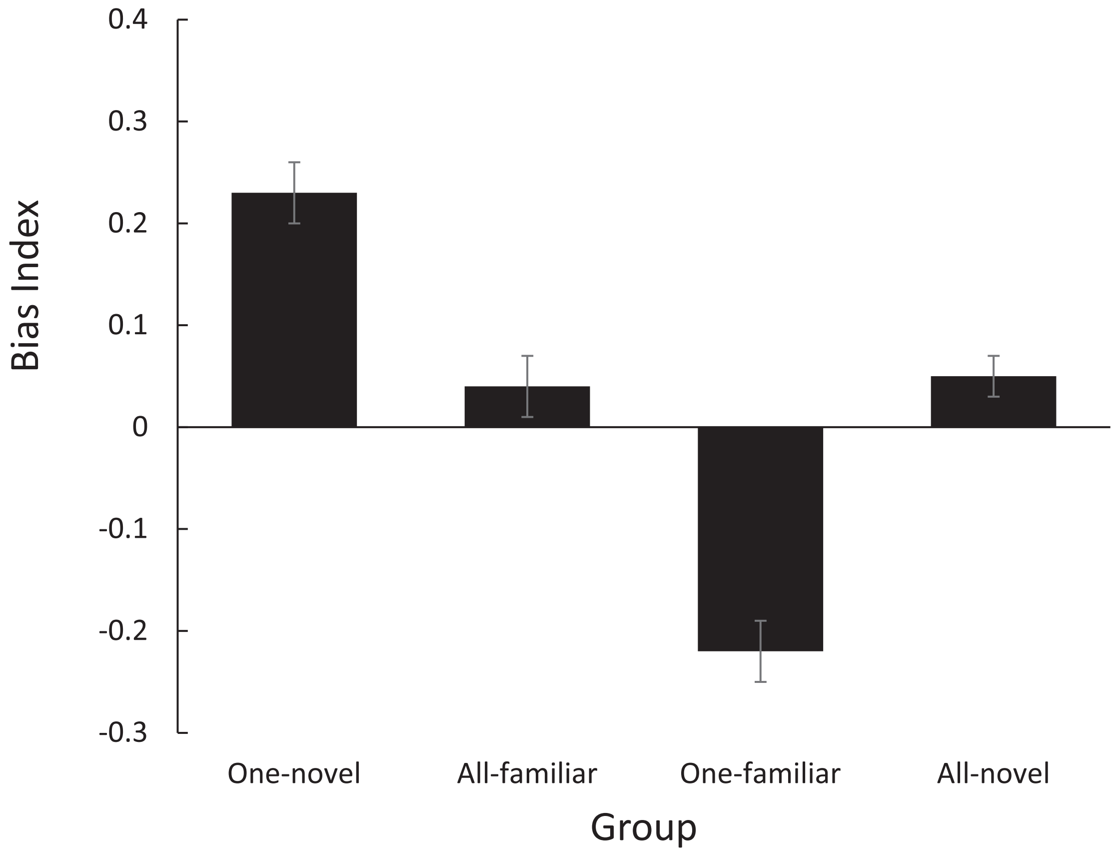

Figure 3. Results from Experiment 2: mean bias index for all four conditions. Error bars, 95% confidence limits.

fatigue, perhaps due to the much longer nature of Experiment 2.

General discussion

The present study aimed to demonstrate pop-out in a paradigm designed to overcome criticisms made of previous demonstrations. It explored the emergence of pop-out under conditions of minimised similarity between stimuli, no memory load, and with displays that were not always task relevant. Novel pop-out occurred in mixed-arrays as initially observed (Johnston et al., 1990; 1993) and survived the several methodological changes suggested by previous criticisms (Christie & Klein, 1995). Novel pop-out occurred with probing items in proportion to their presentation; and not requiring

Table 1. Experiment 2. Mean bias index for each colour, and results of *t*-tests against 0.

Colour	One-novel	All-familiar	One-familiar	All-novel
Red	.30***	.01	−.10***	.03
Cyan	.23***	.01	−.25***	.22
Yellow	.22***	.05	−.23***	.04
Blue	.19***	.01	−.24***	−.05
Green	.21***	.04	−.20***	.04

$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

participants to memorise aspects of targeted stimuli, that may produce confounds in the interpretation of the results.

In relation to the suggestion that the task did not rely on an active/conscious memorisation of locations, some automatic memorial processing may have been involved. When repeating cycles of pre-exposure displays are followed by a single probe, mechanisms of involuntary attention, known as Visual Mismatch Negativity (VMN; Stefanics et al., 2014), can be activated. These repeated stimuli may create memory representations involved in detecting novel stimuli (i.e. those differing from the repeated standards). According to the "texton theory" of pre-attentive vision (Bergen & Julesz, 1983; Julesz, 1984), colour is a texton, and when such a new texton appears, pop-out is produced; when two or more new textons appear, attention is randomly distributed between them, and pop-out is less likely. Thus changing the colour of one block in a probe display draws attention to the block with the changed colour. In probe trials, block colours are visible immediately, while the letters become distinguishable over time as the spatial resolution increases. Consequently, participants' attention is involuntarily drawn to certain blocks, in which they then recognise the words. If there is a non-word in this block, then there is little time to switch attention to another block and recognise the word. This automatic process would explain the bias found for the one-novel condition. If this is an accurate description, then it involves a memory component, but not of the sort suggested as problematic (Christie & Klein, 1995).

Failure to note an identification advantage of words in all-familiar arrays, compared to all-novel arrays, stands in some contrast to previous studies, albeit using different paradigms. For example, previous procedures (Diliberto et al., 2000; Johnston et al., 1999) noted an all-familiar advantage irrespective of pre-exposure procedures. It is unclear what underlies the difference between these studies and the current study, other than the nature of the task. However, this could be the subject of subsequent investigations that attempt to isolate key differences between procedures and manipulate those.

There was some evidence of worse performance for familiar items in mixed-arrays relative to all-familiar items (familiar sink-in). This effect was not noted by Diliberto et al. (2000), but was seen in the studies by Johnston et al. (1990; 1993). The observed (negative) effect/bias in the one-familiar condition could be caused by an inhibition processes (Lubow & Kaplan, 1997; Reed, 1995), such that the one-familiar item is inhibited based on the prior displays and the second word block becomes a relatively "novel" item? It is possible that the nonsignificant finding in Experiment 1 (despite the same pattern observed) was caused by a competition between the relevant colour red (attracting attention + inhibition by previous items) and the second word item. However, caution is needed in making any such interpretation, especially given the statistically inconclusive pattern across studies, and that there is no evidence for this effect when using task-irrelevant displays (McCarthy & Reed, 2023).

Theoretically, the existence of novel pop-out suggests stimulus-array factors be taken into account by models of attention, which need to accommodate that the activation of an object field may be inhibited by repetition. A number of mechanisms are potentially responsible for this effect: repetition increases the negative weighting that dampens event activation (Houghton & Tipper, 1994; Pearce & Hall, 1980); or the repeated event could become associated with nothing, interfering with subsequent association with something (Lubow et al., 2000). Thus when a novel event is presented along with repeated events, in a context where something is to be associated with those events (e.g. a location or a word), the novel event will allow easier association with the salient event, and a larger response will be observed relative to the repeated events. This is reflected in the superior novel-word performance with mixed-arrays, but the all-familiar over all-novel advantage is present when familiar events are relevant to current task demands. That is, bias in favour of repeated events depends on whether these events match the participant's current goal state. Associations from array items to events in the past will only impact responses during test when previously generated responses are consistent with the test response. If previous repetitions of array items involve different response systems, it will offer no advantage of test (and may be detrimental). Thus, when an event is consistently associated with the goal state, there is a development of selection bias. Yet when an event is associated with both goal and non-goal states, little development in selection bias is observed. This proposal is compatible with the latent inhibition literature and consistent various effects observed in the automaticity literature (Killcross & Balleine, 1996; Shiffrin & Schneider, 1977; Tsakanikos & Reed, 2005). Irrespective of which model of attention or explanation is finally accepted, it is clear from the present series of studies that the within-array novel pop-out effect can be obtained, but that the between-array effects may well be sensitive to the task demands of the experimental context.

There are a number of limitations to the current study that subsequent work could address, which have been noted. However, a further consideration is that participants essentially performed a naming task. Although this was irrelevant to the identification, the naming latencies were not recorded, or analysed, which could have produced useful data. It is also a possibility that the use of four white blocks in the pre-exposure displays of the all novel condition, rather than using a colour or colours that were different to those used in the orienting display may have impacted inhibitory processes in this condition. This would need to be explored in further studies.

In summary, the present procedures provided evidence for a within-array pop-out effect, which is central to many bottom-up attentional theories. It has shown the boundary conditions for some of the other effects typically noted in this paradigm. Thus it provides a potentially powerful approach to examining this issue.

Compliance with ethical standards

Disclosure statement: No potential conflict of interest was reported by the author(s).

Research involving human participants and/or animals: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on request.

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