Short Communication

Combined influence of valence and statistical learning on the control of attention: Evidence for independent sources of bias

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A B S T R A C T

Selection history exerts a powerful influence on the control of attention. Stimuli signalling reward and punishment capture attention even when physically non-salient and task-irrelevant. Repeated presentation of a salient distractor at a particular location generates learned suppression, resulting in reduced attentional processing at that location. A debate in the field concerns whether different components of selection history influence attention via a common underlying mechanism of learning-dependent control or via distinct, independent mechanisms. We probed this question with a particular focus on reward/punishment history and learned suppression. Participants were trained to suppress a particular location (high probability distractor location) and associate colours with reward or no outcome (no-reward). In a subsequent task, reward and no-reward distractors appeared in all locations equally often. In a separate experiment, we replaced reward with electric shocks. Reward and shock distractors captured attention more strongly than no-reward and no-shock distractors irrespective of their location. Distractors appearing in the high probability location showed reduced capture irrespective of their type. The results imply that reward and punishment learning and learned suppression have independent influences on the attentional system.

1. Introduction

Our visual system is constantly under a challenge: Its capacity is limited, yet a vast amount of visual input demands processing resources. Attentional selection based on task goals (top-down) and physical salience (bottom-up) has long been considered a resolution to the situation (Corbetta & Shulman, 2002). In addition, recent evidence suggests that prior experience of attending to a particular stimulus or location results in a lingering bias, which guides future attentional selection in favour of repeating prior patterns of orienting. Importantly, such *selection history* biases attention independently of current goals and physical salience (Awh, Belopolsky, & Theeuwes, 2012).

Major components of selection history include (1) reward and punishment history, (2) history as a sought target and (3) statistical regularities. An initially neutral stimulus repeatedly paired with either appetitive or aversive outcomes eventually comes to bias attention even when it is not salient and task-irrelevant (Anderson, Laurent, & Yantis, 2011; Schmidt, Belopolsky, & Theeuwes, 2015). Via associative learning, the stimulus predictive of appetitive or aversive outcomes acquires incentive salience, rendering it more attention-grabbing (Berridge & Robinson, 1998). A neutral stimulus without a predictive association can also bias attention in a similar manner. Whereas the influence of reward history on attention develops rapidly (Sali, Anderson, & Yantis, 2014), with an extended training without reward, a neutral former-target stimulus likewise comes to capture attention (Kim & Anderson, 2019b; Qu, Hillyard, & Ding, 2017).

Statistical regularities regarding distractors can induce learned suppression. After repeated presentation of a distractor at a particular location (high probability location), the location comes to compete less for attention. Search for a target is facilitated when the distractor appears at the high probability location. Importantly, such learned suppression is generated by selection history independent of top-down and bottom-up control (Failing, Feldmann-Wüstefeld, Wang, Olivers, & Theeuwes, 2019; Wang, Driel, Ort, & Theeuwes, 2019; Wang & Theeuwes, 2018a, 2018b, 2018c).

While substantial research has identified different components of selection history, how the mechanisms by which they influence the attentional system relate to one another remains to be explored. There

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are a number of possibilities. If the components are the product of a common overarching mechanism governing learning-dependent attentional control, such as visual statistical learning (Failing & Theeuwes, 2018; Theeuwes, 2019), they would interact to be integrated into a single source of bias and jointly guide attention, interfering or otherwise competing with each other for limited attentional resources. Alternatively, each may be fundamentally distinct and thus influence attention independently. Evidence that reward and punishment history on the one hand and history as a sought target on the other hand produce independent sources of bias (Anderson, Chiu, DiBartolo, & Leal, 2017; Anderson, Laurent, & Yantis, 2014; Kim & Anderson, 2019a, 2019b, 2020; see also Stankevich & Geng, 2014) suggests that learned suppression could also be an independent source of attentional bias.

Among the different components of selection history, the present study examined reward history, punishment history, and statistical regularities. Specifically, we probed whether reward (Experiment 1) and punishment (Experiment 2) signalling stimuli and learned suppression based on statistical regularities in the location of distractors would interact or produce independent effects. Given that reward and punishment associations exert a powerful influence on attention that is resistant to top-down suppression (Anderson et al., 2011; Munneke, Belopolsky, & Theeuwes, 2016; Munneke, Hoppenbrouwers, & Theeuwes, 2015; Pearson, Watson, Cheng, & Le Pelley, 2020; Schmidt et al., 2015), we expected that valent distractors would capture attention regardless of the location in which they appeared. We also expected additive effects of the two components, consistent with the independent source of bias account.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Forty-one participants (24 females; mean age = 21.9 years) were recruited from the Texas A&M University community. Participants were compensated with money earned in the experiment. All reported normal or corrected-to-normal visual acuity and normal colour vision. All procedures were approved by the Texas A&M University Institutional Review Board and conformed with the principles outlined in the Declaration of Helsinki. A power analysis using power 1-β = 0.8, α = 0.05 and an effect size (d_z = 0.54) found in prior studies that examined learned suppression (Wang & Theeuwes, 2018a, 2018b) and attentional bias towards reward and threat (Kim & Anderson, 2019a, 2020) informed that a sample size of n = 29 would be needed to detect a main effect of valence or location. A sensitivity power analysis with the

resulting sample size of n = 82 (Experiments 1 and 2 combined; see *3.2.3 Combined analysis*) at power 1-β = 0.8 and α = 0.05 allowed detection of an interaction effect as small as η_p^2 = 0.024.

2.1.2. Apparatus

A standard Windows computer equipped with MATLAB software and Psychophysics Toolbox was used to present stimuli on a Dell P2717H monitor. The eye-to-screen distance was approximately 70 cm. Responses were entered using a standard keyboard.

2.1.3. Procedure

2.1.3.1. Training phase. Participants completed in total 612 trials, divided into four runs. Each trial consisted of a fixation display (400–600 ms), a search display (1500 ms or until response), and a feedback display (1500 ms for reward and 1000 ms for performance feedback), in addition to inter-stimulus and inter-trial intervals (Fig. 1). The search display included a uniquely shaped target and five differently shaped distractors (i.e., a circle target among diamond distractors or vice versa; 3.6° x 3.6°) positioned around an imaginary circle with a radius of 10.6°. The target contained either a horizontal or vertical line segment. Participants were instructed to search for a unique shape target regardless of colour and identify the orientation of the line within the target with a keypress.

There were four trial types. On salient distractor absent/neutral target trials (72 trials), all shapes appeared in grey. On reward and no-reward target trials (180 trials each), the target was rendered in one of three colours (red, green and blue). Correct responses on reward target trials resulted in a reward of eight cents. No reward was given on no-reward target trials (or any other trial that did not contain the rewarded target). In these three trial types, targets appeared in each of six locations equally often. On salient distractor present trials (180 trials), one of the distractors was rendered in a colour not used for the reward and no-reward targets. Critically, this salient distractor appeared in one location more often (high probability location; 66.7% of salient distractor trials). Targets were equally likely to appear in a location not occupied by the salient distractor on a given trial (fully counterbalanced on high probability distractor trials and pseudorandomised on low probability distractor trials such that the spatial distribution was approximately equal). The high probability location and colour-to-condition mapping were counterbalanced across participants. The target was equally often a diamond among circles and a circle among diamonds.

The feedback display was presented on correct reward target trials and any incorrect trials. On correct reward target trials, the display
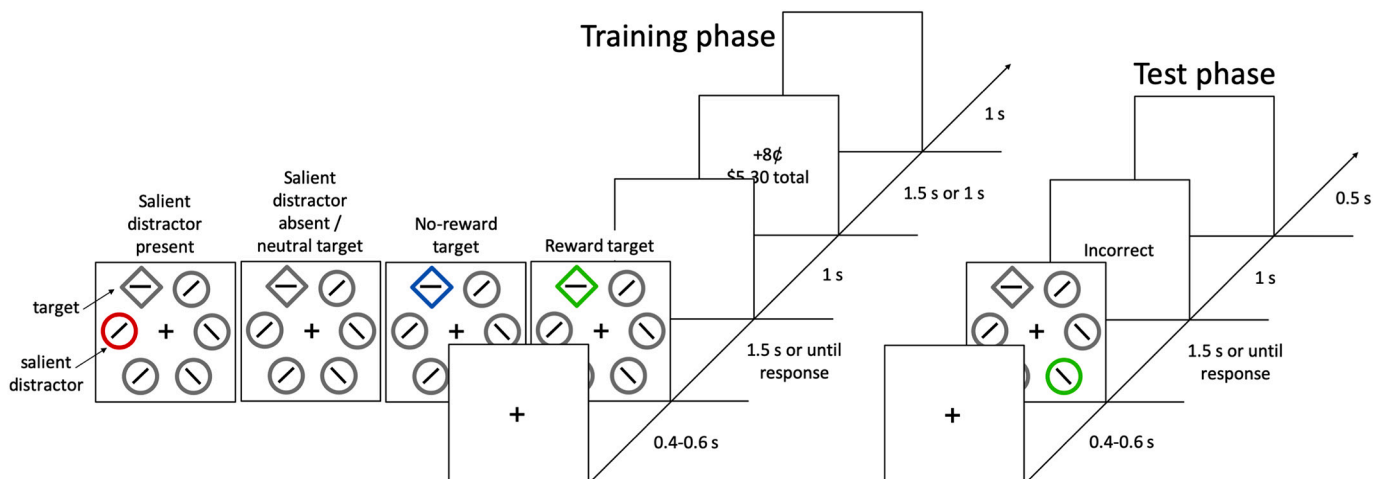

Fig. 1. Sequence of trial events.

consisted of the money earned on the current trial and the total amount earned. On incorrect trials, the display presented "Incorrect" if an incorrect response was entered or "Too slow" if no response was entered before the search display timed out.

2.1.3.2. Test phase. Participants completed 480 trials divided into four runs. Each trial consisted of a fixation display (400–600 ms), a search display (1500 ms or until response), and (if too slow or incorrect) a feedback display (1000 ms), in addition to a blank inter-trial interval (Fig. 1). The search display was identical to that of the training phase, except that there were three types of trials. On salient distractor absent trials (120 trials), all shapes appeared in grey. Targets appeared in each location equally often. On reward and no-reward distractor trials (180 trials each), one of the distractors appeared in the colour associated with reward and no-reward, respectively. The distractor appeared in each location equally often. Instructions for participants remained similar, except that they were informed they cannot earn money in this phase and coloured shapes would never appear as a target.
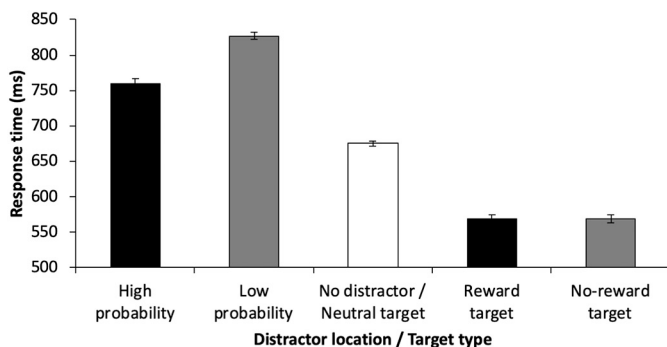
2.2. Results

RTs faster than 200 ms or exceeding 2.5 SDs of the mean for each condition for a given participant were excluded.

2.2.1. Training phase

RTs and error rate from the training phase were subjected to a repeated-measures ANOVA with salient distractor location (high probability location, low probability location and no distractor) as a factor. There was an effect of distractor location on RT, $F(2, 80) = 279.63$, $p < 0.001$, $\eta_p^2 = 0.88$. Planned contrasts revealed RTs were significantly slower when the salient distractor appeared in the high and low probability locations compared to when there was no distractor, $ts > 11.85$, $ps < 0.001$, $ds > 1.84$. Importantly, the capture effect was reduced when the salient distractor appeared in the high probability location compared to the low probability location, $t(40) = -13.56$, $p < 0.001$, $d = 2.13$. The effect of learned suppression was further supported by a paired-samples *t*-test that examined target selection efficiency on distractor absent trials. RTs were faster when the target appeared in the low probability location (673 ms) than when it appeared in the high probability location (706 ms), $t(40) = 3.44$, $p = 0.001$, $d = 0.54$.

A similar pattern was observed for error rate, $F(2, 80) = 23.93$, $p < 0.001$, $\eta_p^2 = 0.37$. Error rate was lower on distractor absent trials, compared to high and low probability location trials, $ts > 4.7$, $ps < 0.001$, $ds > 0.73$. Fewer errors were made on high probability location trials than low probability location trials, $t(40) = -3.3$, $p = 0.002$, $d = 0.52$. There was no difference in error rate between trials on which the target appeared in the high probability location and in the low probability location, $t(40) = 1.32$, $p = 0.19$.

A repeated-measures ANOVA with target type (reward, no-reward and neutral) as a factor revealed a significant effect on RT, $F(2, 80) =$ 202.43, $p < 0.001$, $\eta_p^2 = 0.84$. RTs were faster for the reward and no-reward targets than the neutral target, $ts > 14.22$, $ps < 0.001$, $ds > 2.22$. There was no difference in RTs between the reward and no-reward targets, $t(40) = 0.26$, $p = 0.8$. A similar pattern was observed for error rate, $F(2, 80) = 3.57$, $p = 0.033$, $\eta_p^2 = 0.08$. Fewer errors were made on the no-reward target trials than neutral target trials, $t(40) = -2.38$, $p = 0.022$, $d = 0.37$. No other comparisons were significant, $ts < 1.59$, $ps > 0.11$ (Fig. 2).

2.2.2. Test phase

Pairwise comparisons demonstrated that RT was slower in all four of the distractor conditions (reward and no-reward distractors in high and low probability locations) compared to distractor absent trials, $ts > 4.9$, $ps < 0.001$, $ds > 0.78$, confirming robust attentional capture by the physically salient distractors. Subsequent analyses focus on comparisons among the distractor conditions. RTs and error rate from the test phase were subjected to a 2 × 2 repeated-measures ANOVA with salient distractor location (high probability location and low probability location) and distractor type (reward and no-reward) as factors. The reward distractor slowed RTs relative to the no-reward distractor, $F(1, 40) = 4.91$, $p = 0.032$, $\eta_p^2 = 0.11$, suggesting that value modulated attentional capture. When these distractors appeared in the high probability location, RTs were faster than when they appeared in the low probability location, $F(1, 40) = 5.96$, $p = 0.019$, $\eta_p^2 = 0.13$, indicative of reduced capture effect due to spatial suppression. There was no significant interaction, $F(1, 40) = 0.09$, $p = 0.77$. No significant effects were observed for error rates, all $Fs < 2.06$, all $ps > 0.15$ (Fig. 3).

A possible explanation for the null interaction effect is that extinction of learned suppression and/or value-modulated attention over time abolishes an interaction effect that is present when these main effects are more pronounced. If so, we may expect a more robust interaction effect in earlier parts of the test phase. We probed this possibility with RTs
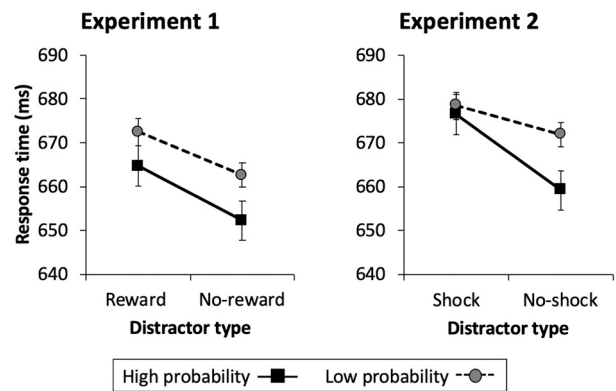

Fig. 3. Mean response time by condition from the test phase of Experiment 1 (left) and Experiment 2 (right). Error bars represent the within-subjects SEM.
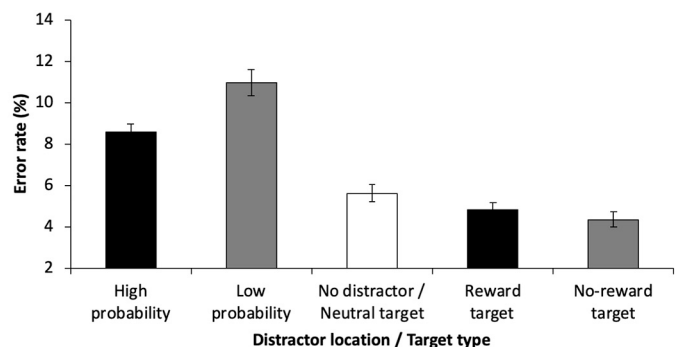

Fig. 2. Mean response times and error rates from the training phase of Experiment 1. Error bars represent the within-subjects SEM.

from the first half of the test phase (Runs 1 and 2 combined), but again found no evidence for an interaction effect, $F(1, 40) = 0.08$, $p = 0.77$ (see supplementary data).

We also examined efficiency of target selection on distractor absent trials. A paired t-test on RT and error rate comparing trials on which the target appeared in the high probability location and low probability location revealed no difference between the two locations, $ts < 1.16$, $ps > 0.25$.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Forty-three participants (25 females; mean age = 19.4 years) were recruited from the Texas A&M University community. Participants were compensated with course credit. All reported normal or corrected-to-normal visual acuity and normal colour vision. All procedures were approved by the Texas A&M University Institutional Review Board and conformed with the principles outlined in the Declaration of Helsinki.

3.1.2. Apparatus

Set-up was equivalent to that of Experiment 1. Electric shocks were generated by an isolated linear stimulator (BIOPAC) operating in current mode.

3.1.3. Procedure

3.1.3.1. Shock calibration. Electric shocks were delivered via electrodes attached to participants' left forearm. Shock intensity was adjusted by gradually increasing it to a level where participants perceived it as uncomfortable but not painful (as in, e.g. Kim & Anderson, 2020; Schmidt et al., 2015).

3.1.3.2. Training phase. Training phase was identical to that of Experiment 1, unless otherwise stated. Participants completed in total 444 trials, divided into four runs. There were four trial types; salient distractor absent/neutral target trials (72 trials), shock target trials (96 trials), no-shock target trials (96 trials) and salient distractor trials (180 trials). All search displays were followed by a feedback display. The feedback display presented "Correct" following a correct response and either "Incorrect" or "Too slow" following a response that was not correct. On shock target trials, shocks were delivered on 40% of the trials, simultaneously with the feedback display.

3.1.3.3. Test phase. Test phase was identical to that of Experiment 1. Participants were informed they would no longer receive shocks in the test phase.

3.2. Results

Data from two participants were excluded from analyses due to withdrawal from the study and accuracy below chance-level. All analysis procedures were identical to those of Experiment 1.

3.2.1. Training phase

There was an effect of distractor location on RT, $F(2, 80) = 176.49$, $p < 0.001$, $\eta_p^2 = 0.82$. Salient distractors appearing in high and low probability locations captured attention relative to when there was no distractor, $ts > 9.20$, $ps < 0.001$, $ds > 1.43$. The capture effect was reduced when the salient distractor appeared in the high probability location, $t(40) = -13.35$, $p < 0.001$, $d = 2.09$. Distractor absent trial RTs further supported the effect of learned suppression; they were faster when the target appeared in the low probability location (713 ms) than when it appeared in the high probability location (746 ms), $t(40) = 4.14$, $p < 0.001$, $d = 0.64$.

Error rates also exhibited an effect of distractor location, $F(2, 80) = 28.44$, $p < 0.001$, $\eta_p^2 = 0.42$. More errors occurred when a distractor appeared in the low probability location than in the high probability location and when there was no distractor, $ts > 5.19$, $ps < 0.001$, $ds > 0.8$. Error rates on high probability location trials and distractor absent trials were comparable, $t(40) = 1.15$, $p = 0.26$. Distractor absent trial error rates revealed that participants made fewer errors when the target appeared in the low probability location (5.9%) than when it appeared in the high probability location (8.7%), $t(40) = 2.45$, $p = 0.019$, $d = 0.38$.

There was an effect of target type on RT, $F(2, 80) = 109.79$, $p < 0.001$, $\eta_p^2 = 0.73$. RTs were faster for the shock and no-shock targets than the neutral target, $ts > 10.62$, $ps < 0.001$, $ds > 1.65$. There was no difference in RTs between the shock and no-shock targets, $t(40) = 1.44$, $p = 0.16$. A similar pattern was observed for error rate, $F(2, 80) = 7.14$, $p = 0.001$, $\eta_p^2 = 0.15$. Fewer errors were made on the shock and no-shock target trials than neutral target trials, $ts > 2.56$, $ps < 0.02$, $ds > 0.4$. There was no difference between the shock and no-shock target trials, $t(40) = 0.98$, $p = 0.34$ (Fig. 4).

3.2.2. Test phase

Pairwise comparisons demonstrated that RT was slower in all four of the distractor conditions compared to distractor absent trials, $ts > 2.26$, $ps < 0.03$, $ds > 0.35$, confirming robust attentional capture by the physically salient distractors. Subsequent analyses focus on comparisons among the distractor conditions, as in Experiment 1.

The shock distractor slowed RTs relative to the no-shock distractor, $F(1, 40) = 9.03$, $p = 0.005$, $\eta_p^2 = 0.18$, indicative of threat-modulated attentional capture. There was a marginal effect of distractor location, $F(1, 40) = 3.16$, $p = 0.08$, $\eta_p^2 = 0.07$, with slower RT when a distractor appeared in the low probability location than in the high probability location, but no interaction, $F(1, 40) = 2.62$, $p = 0.11$. The interaction effect was not significant even in the first half of the test phase, $F(1, 40) < 0.001$, $p = 0.997$ (see supplementary data). More errors occurred when a distractor was in the high probability location than in the low probability location, $F(1, 40) = 4.72$, $p = 0.036$, $\eta_p^2 = 0.11$. No other effects were significant, all $Fs < 0.48$, all $ps > 0.49$ (Fig. 3).

RTs from distractor absent trials were faster when the target appeared in the low probability location (639 ms) than high probability location (661 ms), $t(40) = 2.16$, $p = 0.037$, $d = 0.34$, indicative of spatial suppression at the high probability location. No significant difference was found for error rate, $t(40) = 0.86$, $p = 0.39$.

3.2.3. Combined analysis

Given the similar pattern of results across the two experiments, we ran a three-way ANOVA on RTs in the test phase with distractor location (high probability and low probability), distractor valence (valent [reward/shock] and no-valence [no-reward/no-shock]) and experiment (1 and 2) as factors to compare the effects of reward and punishment learning. Other than main effects of distractor location, $F(1, 80) = 7.84$, $p = 0.006$, $\eta_p^2 = 0.1$ and distractor valence, $F(1, 80) = 14.65$, $p < 0.001$, $\eta_p^2 = 0.16$, no other effects were significant, $Fs < 1.48$, $ps > 0.22$, suggesting reward and punishment learning produced a similar pattern of results. This was corroborated by a Bayesian ANOVA which determined that a model with only the two main effects best represents the data, $BF_{10} = 938.43$. Relative to this best model (and assuming the a priori probability [prior] of each possible model was equally-likely), a model that includes an interaction between valence and location is $BF_{10} = 0.3$, which provides moderate evidence against an interaction. These results suggest that reward and punishment learning and statistical regularities have independent influences on attention. In addition, any model that includes the factor experiment was unlikely, both with respect to the addition of a main effect of experiment, $BF_{10} = 0.58$, as well as any model containing any interaction with experiment, $BF_{10} < 0.105$, suggesting that reward and punishment learning produce a similar pattern
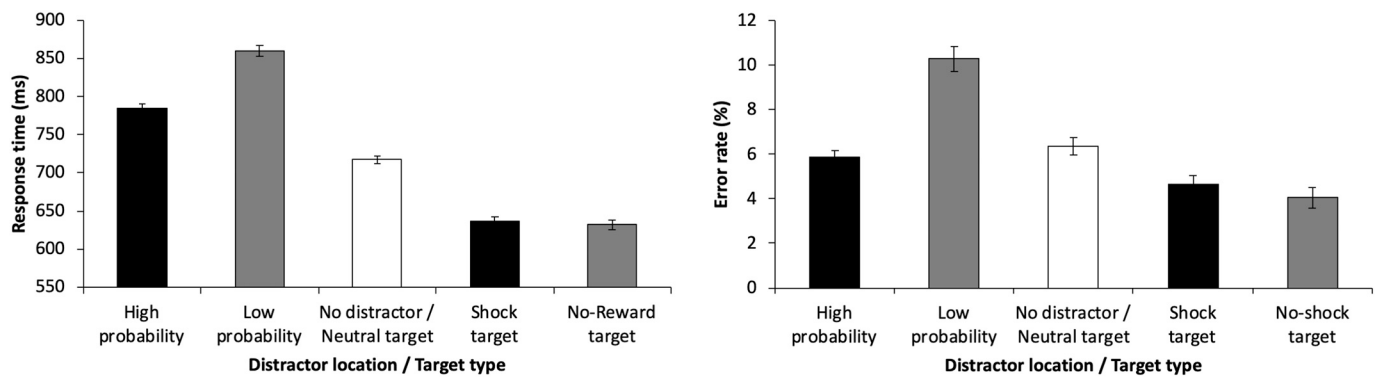
Fig. 4. Mean response times and error rates from the training phase of Experiment 2. Error bars represent the within-subjects SEM.

with respect to the orienting of attention.

4. General discussion

In two experiments, we showed that valence-modulated orienting and learned suppression have independent influences on attention. Stimuli signalling reward and punishment captured attention and learned suppression that developed in the high probability location reduced the capture effect. Value- and threat-based attentional orienting shared a similar profile, and the additive pattern of results suggests reward/punishment learning and statistical regularities are independent sources of bias to the attentional system.

The similar effects of reward and punishment learning demonstrated in the present study are consistent with the idea that the attentional system is primarily guided by motivational salience rather than a particular valence. Indeed, only by prioritising behaviourally relevant – both appetitive and aversive – events can an organism ensure its survival (Brosch, Sander, Pourtois, & Scherer, 2008; Gable & Harmon-Jones, 2010). Evidence in support of this view has demonstrated that reward- and punishment-signalling stimuli influence attention in a similar manner (Anderson et al., 2011; Kim & Anderson, 2019a, 2020; Schmidt et al., 2015). Such valence-independent representation of stimuli associated with reward and punishment is supported by brain mechanisms that prioritise motivational salience. Many of the brain areas traditionally thought to be dedicated to the processing of either appetitive or aversive information are now known to process both types of information (Lindquist, Satpute, Wager, Weber, & Barrett, 2016; Liu, Hairston, Schrier, & Fan, 2011; Vuilleumier, 2015). A subpopulation of dopamine neurons in the substantia nigra transmits motivational salience signal to the dorsal striatum, which in turn elicits an automatic orienting response (Matsumoto & Hikosaka, 2009).

Following the proposal of selection history as a third mechanism of attentional selection (Awh et al., 2012), selection history has been regarded as a large category of attentional control that differs fundamentally from goal-driven and stimulus-driven control. Substantial research has identified different components of selection history, such as associations between stimuli and valent outcomes and the frequency of targets and distractors appearing at particular spatial locations. One possibility is that these components reflect the influence of a common underlying mechanism (Failing & Theeuwes, 2018; Theeuwes, 2019).

Unlike this view, we propose that the valence associated with stimuli and the frequency with which stimuli appear at particular spatial locations have unique contributions to the attentional system that need to be examined separately. The additive effects of associative learning and statistical learning are consistent with studies that demonstrate independent influences of different components of selection history. For example, although reward/punishment history and history as a sought target share a similar behavioural profile with respect to how they bias attention, different learning processes contribute to the development of

such history effects. Reward and punishment history develop via associative learning, in which a predictive relationship between a stimulus and reward/punishment is established. As a result, the stimulus that predicts the outcome comes to elicit an automatic orienting response even after reinforcement is discontinued. On the other hand, instrumental learning shapes history as a sought target by establishing a response-outcome association (Kim & Anderson, 2019a, 2020). The exact learning mechanism responsible for the learned suppression effect remains to be determined, but our results imply that it would be fundamentally distinct from that for reward and punishment learning.

In addition, the additive pattern of results suggests that different components of selection history rely on at least partially distinct neural substrates to produce a similar behavioural profile. Reward and punishment learning involves the dopaminergic basal ganglia system in which the caudate tail encodes value information and elicits habitual orienting towards stimuli associated with reward and punishment (Anderson et al., 2014; Ghazizadeh, Griggs, & Hikosaka, 2016; Kim, Ghazizadeh, & Hikosaka, 2015). In addition, heightened attentional priority is afforded by enhanced representation of such stimuli in the visual cortex (Anderson et al., 2014; Itthipuripat, Vo, Sprague, & Serences, 2019). On the other hand, history as a sought target develops primarily via plasticity in the visual cortex (Makino, Hwang, Hedrick, & Komiyama, 2016). Importantly, attentional orienting to former targets does not involve the reward circuit (Kim & Anderson, 2019b). Attentional orienting based on statistical regularities also relies on distinct neural mechanisms. A candidate for assigning attentional priority on the basis of regularities is the hippocampus which rapidly extracts regularities (Theeuwes, 2019). Indeed, contextual cueing in which target detection is facilitated by distractor regularities is mediated by the hippocampus (Chun & Phelps, 1999). At the same time, suppression of repeated distractors can be achieved via visual plasticity (Adam & Serences, in preparation), just like in the case of reward/punishment history and history as a sought target. The spatial suppression observed in the present study may involve a similar neural mechanism. Together, these findings challenge the view that selection history is a unitary mechanism of experience-dependent attentional control (Failing & Theeuwes, 2018; Theeuwes, 2019) and suggest a more fractionated view of the nature of selection history. Our findings suggest that different components of selection history reflect distinct sources of bias that are not integrated through a single (unitary) representation of learning-dependent priority but maintain their independence until they reach a common (general) priority map.

A limitation of the present study is that the two components of selection history examined were tied to different dimensions – learned suppression was spatial whereas valence learning was featural. Although our results are inconsistent with a common overarching mechanism of learning-dependent attentional control that spans feature dimension, it is possible that a more robust interaction effect would be evident within a feature dimension. Future research should consider

manipulating the two components of selection history within a single dimension.

4.1. Conclusions

In conclusion, the present study demonstrates that valence-based attentional priority arising from associative learning and location-based suppression arising from statistical learning have distinct effects on attentional priority. Reward and shock distractors captured attention more strongly than no-reward and no-shock distractors irrespective of their location. Distractors at the high probability location reduced capture irrespective of their valence, with no evidence for an interaction between valence and location. Together, our results suggest that the two underlying components of selection history – statistical regularities and associative learning – influence attention independently.

Author contributions

BAA and HK conceived of the experiment. HK programmed the experiment and led data collection efforts. BAA and HK analysed the data. HK drafted the manuscript, which BAA edited.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2020.104554.

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