Behavioral Neuroscience

Primary Rewards and Aversive Outcomes Have Comparable Effects on Attentional Bias

Haena Kim and Brian A. Anderson

Online First Publication, December 15, 2022. https://dx.doi.org/10.1037/bne0000543

CITATION

Kim, H., & Anderson, B. A. (2022, December 15). Primary Rewards and Aversive Outcomes Have Comparable Effects on Attentional Bias. *Behavioral Neuroscience*. Advance online publication. https://dx.doi.org/10.1037/bne0000543

AMERICAN PSYCHOLOGICAL ASSOCIATION

Behavioral Neuroscience

ISSN: 0735-7044

https://doi.org/10.1037/bne0000543

BRIEF COMMUNICATION

Primary Rewards and Aversive Outcomes Have Comparable Effects on Attentional Bias

Haena Kim and Brian A. Anderson
Department of Psychological and Brain Sciences, Texas A&M University

Attention is biased toward stimuli previously associated with reward. The same is true for aversive conditioning; stimuli previously associated with an aversive outcome also bias attention, suggesting that motivational salience guides attention. Most research that supports this conclusion has manipulated monetary gain—a secondary reinforcer—for reward learning, and electric shocks—a primary punisher—for aversive conditioning, making it difficult to directly compare their influence on attention. Therefore, in the present study, we matched for reinforcer dimensions by using primary taste as reinforcers/punishers and assessed their influence on attention. In a training phase, participants learned to associate three colors with sweet juice (reward), salt water (aversive), and no outcome (neutral), respectively. The two primary reinforcers were equated for valence based on choices made in a prior decision-making task. In a later test phase, these three colors were used for targets and distractors in a task in which participants oriented to a shape-defined target. An attentional bias in favor of the aversively conditioned and reward-associated colors was evident when comparing to the neutral color. Importantly, a direct comparison of rewarded and aversive stimuli revealed no significant differences. These results suggest that when matched for reinforcer dimensions and valence, reward and aversive outcomes bias attention in a similar manner and their effects are comparable, providing further evidence in support of the motivational salience account of learning-dependent attention.

Keywords: selection history, selective attention, reward learning, aversive conditioning, primary incentives

Which stimuli receive attentional processing is the joint product of current task goals, physical salience, and *selection history*, or how attention has been allocated to different stimuli in the past (Anderson et al., 2021; Awh et al., 2012). Research on the influence of selection history on attention has suggested a comparable influence of reward and punishment history. Initially, neutral stimuli repeatedly paired with a reward or aversive outcome acquire elevated attentional priority via an associative learning mechanism (Bucker & Theeuwes, 2017; Kim & Anderson, 2019, 2021; Le Pelley et al., 2015), such that they bias attention even when they are neither physically salient nor task-relevant (referred to as value-driven or threat-driven attentional capture; e.g., Anderson et al., 2011; Schmidt et al., 2015). These stimuli also share a common neural profile; they evoke a similar pattern of activation within the dopaminergic mid-brain structures and striatum, including the caudate tail (Anderson et al., 2014; Kim et al., 2021). Although findings are somewhat mixed with respect to how stimuli previously associated with monetary loss are processed by the attentional system (Barbaro et al., 2017; Becker et al., 2020; Wang et al., 2013; Wentura et al., 2014; Zhuang et al., 2021), attention is consistently biased toward stimuli associated with primary aversive unconditioned stimuli such as electric shock (Kim et al., 2021; Schmidt et al., 2015) and loud noise (Koster et al., 2004; Smith et al., 2006), as it is with reward (see Anderson et al., 2021). These findings are consistent with an influence of motivational salience on the control of attention in that both reward and aversive outcomes are relevant for survival, and attentional biases toward stimuli associated with these outcomes facilitate preparation of an appropriate response (Gable & Harmon-Jones, 2010).

There is a limitation that has consistently been raised when comparing the effects of reward and punishment history in attention research, however. Most reports on value-driven attention utilized financial incentives, which are secondary reinforcers, whereas those on threat-driven attention used electric shocks, which are primary punishers. Although prior findings support the idea that their effects are similar despite such dimensional difference, there remains the possibility that outcomes of different dimensions have dissociable

Haena Kim is now at Department of Psychology, University of Chicago.

This study was supported by National Institutes of Health Grant R01-DA046410 to Brian A. Anderson. The authors have no conflict of interest to disclose.

The data are available upon request made to the corresponding author and will be provided under the provision that the data be used strictly for academic research purposes and not be shared with others without the express written approval of the corresponding author.

Haena Kim played a lead role in conceptualization, data curation, formal analysis, writing of original draft, and writing of review and editing. Brian A. Anderson played a lead role in conceptualization, data curation, formal analysis, funding acquisition, and writing of review and editing.

Correspondence concerning this article should be addressed to Haena Kim, Department of Psychology, University of Chicago, Chicago, Illinois 60637, United States. Email: kimhannah@uchicago.edu

effects on behavior, which complicates direct comparison. For example, neuroimaging evidence suggests that primary (e.g., food, water) and secondary (e.g., money) reward values are represented in anatomically distinct regions of the brain (Beck et al., 2010; Levy & Glimcher, 2011; Sescousse et al., 2010, 2013). Therefore, in the present study, we matched for outcome dimensions by using primary tastes and compared the effects of reward and punishment history on attention.

It is not without precedent that studies on value-driven attention have used primary rewards as outcomes. For example, a neutral stimulus paired with chocolate odor is capable of attracting attention (Pool et al., 2014). It is also possible to induce value-driven attentional capture only by showing an image of a glass filled with water as an outcome during training that later translates to actual water for thirsty participants (De Tommaso et al., 2017). However, to our knowledge, how punishment history shaped by an aversive primary outcome influences attention has not yet been examined in relation to a measurement of attention to a primary reward cue. Therefore, we used participants' preferred drink as a reward and salt solution as an aversive outcome to shape reward and punishment history.

Using the delivery of these liquids as outcomes, the present study compared the effects of reward and punishment history on attention. We used flavored liquid as outcomes to match for the sensory modality involved in processing reward and aversive outcomes, thereby eliminating any confounding effect that may come from a difference in sensory modality. We also estimated the minimum amount of reward solution needed to offset the aversiveness of salt solution (i.e., point of subjective equality) for each participant and used these amounts of reward and salt solutions in the training and test phases. Comparable effects of reward and punishment history after controlling for valence in this way would provide further support for the motivational salience account of selection history. We expected that the magnitude of capture induced by stimuli predictive of reward and salt solutions compared to a neutral stimulus that predicts no outcome would be similar, and that a direct comparison between reward- and salt-predictive stimuli would yield evidence in favor of the null hypothesis. To the degree that reward and aversive outcome independently bias attention, rather than via a common mechanism linked to motivational salience, with valence equated we might expect either reward (Barbaro et al., 2017) or aversive outcome (Galea et al., 2015; Kahneman & Tversky, 1979; Kubanek et al., 2015) to exert a stronger influence on attentional control, with theoretical accounts disagreeing on which type of outcome is the stronger driver of behavior.

Method

Participants

Fifty-two participants (36 females; $M_{\text{age}} = 21.5$ years) were recruited from the Texas A&M University community. All participants had normal or corrected-to-normal visual acuity, normal color vision, and refrained from drinking for at least 3 hr prior to the experiment. With the effect size $d = 0.52$ reported in Kim et al. (2021) which used a similar task, the sample size provided power $1 - \beta > 0.9$ with $\alpha = 0.05$. All procedures were approved by the Texas A&M University institutional review board and conformed with the principles outlined in the Declaration of Helsinki.

Apparatus

A standard Windows computer equipped with MATLAB software and Psychophysics Toolbox (Brainard, 1997) was used to present stimuli on a Dell P2717H monitor. The eye-to-screen distance was approximately 70 cm. Eye position was monitored using an EyeLink 1000 Plus Desktop mount eye tracker. Reward and salt solutions were delivered via a pacifier and two polyvinyl chloride tubing (Yee et al., 2021), each connected to two syringes loaded on New Era NE-1000 syringe pumps. The syringe pumps were controlled via MATLAB.

Procedure

The study required two visits. On the first day, participants completed a liquid-rating procedure and a decision-making task. On the following day, participants completed four runs of 60 training phase trials and three runs of 96 test phase trials.

Liquid Rating

Participants chose their favorite drink from a list of available beverages (sports drink, apple juice, sweet tea, and Kool-Aid) as the reward solution, tasted 0.5 ml of the chosen solution, and rated it on a 0 (*extremely unpleasant*) to 10 (*extremely pleasant*) pleasantness rating scale. Participants also tasted different concentrations of salt solution (0.6 M, 0.8 M, 1.0 M, and 1.2 M) and rated each solution on the same scale. The concentration that evoked (or most closely evoked) a "2" was used for the experiment.

Decision-Making Task

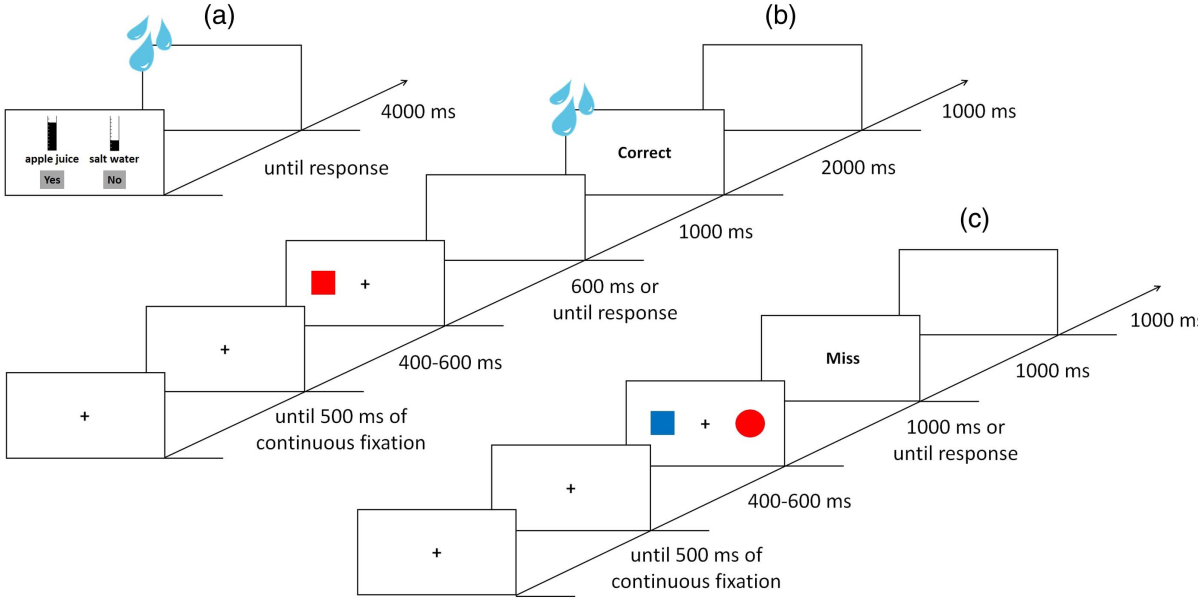
The decision-making task was designed to determine the minimum amount of reward solution required to offset the aversiveness of salt solution (i.e., point of subjective equality with respect to valence). On each trial, participants were presented with a visual depiction of two cylinders. Each cylinder contained a certain amount of the reward solution and salt solution, ranging from 0.1 ml to 1 ml. The amount of solutions in the two cylinders always summed to 1.1 ml, resulting in 10 different combinations of amounts. Participants were instructed to decide whether to place a bet or not. If they decided to place a bet, one of the solutions was randomly selected, and the amount indicated was directly delivered to their mouth. No solution was delivered if participants chose not to place a bet. Participants completed a total of 160 trials (Figure 1a). In order to determine the point of subjective equality, we fit a regression and computed the amount of each solution to be used in all subsequent tasks.

Training Phase

Each trial consisted of a fixation display, a stimulus display, and a feedback display (Figure 1b). Participants were instructed to look at the fixation cross, and the trial progressed after 500 ms of continuous fixation had been recorded. The fixation display stayed on the screen for an additional 400–600 ms (randomly determined on each trial) before the stimulus display appeared. The stimulus display contained a target square (3.7° × 3.7°) either on the left or right, 11.1° from the fixation cross. The target square appeared in one of the three equiluminant colors (red, blue, and green). One color target was followed by a reward solution on 80% of the trials on which it

Figure 1

Sequence of Trial Events for (a) Decision-Making Task, (b) Training Phase, and (c) Test Phase



Note. See the online article for the color version of this figure.

was presented, and no outcome otherwise (reward target trials). Another color target was followed by a salt solution on 80% of the trials on which it was presented, and no outcome otherwise (salt target trials). The remaining color target was never followed by a solution outcome (neutral target trials). Which color was assigned to which outcome was counterbalanced across participants. The neutral color target was matched for history as a former target but not associated with an outcome, thereby controlling for selection history as is typically done in this paradigm (Anderson et al., 2021). Participants were instructed to make a saccade to the target square. After a blank screen for 1,000 ms, feedback ("correct" or "incorrect") was presented for 2,000 ms, simultaneously with reward or salt solution delivery if delivery was to occur on the trial. Each color target appeared on each side of the screen equally often, and trials were presented in a random order. Practice for the training phase consisted of 30 trials in which a white square was used for the target, and no outcomes were delivered. At the end of the training phase, participants were asked to rate the reward and salt solutions they tasted during the training phase on the same 0–10 scale.

Test Phase

Each trial consisted of a fixation display, a search display, and a feedback display (Figure 1c). As in the training phase, participants had to look at the fixation cross to begin. The search display contained a target circle (3.7° in diameter) and a distractor square (3.7° × 3.7°), one on each side, 11.1° from the fixation cross. The target was presented equally often on the left and right. Each shape appeared in one of the three colors used in the training phase equally often, and they never appeared in the same color on a given trial. Target/distractor color and location were fully crossed and counterbalanced, and trials were presented in a random order. Participants were instructed to make a saccade to the target circle. Saccades that remained in the target circle window (1.5 times the target size) for longer than 100 ms were scored as correct. If participants made an errant saccade to the distractor square window (1.5 times the distractor size), the trial was scored as containing an errant eye movement. Feedback ("miss") was provided only on trials where participants failed to fixate the target before the trial timed out. Practice for the test phase consisted of 32 trials in which the stimulus display contained white shapes. Participants were explicitly informed of no outcome delivery in the test phase.

Results

Response times (RTs) faster than 200 ms or exceeding 2.5 *SD*s of the mean for each condition for a given participant were excluded. Error rates from the test phase were defined as the proportion of trials containing an initial saccade to the distractor. Given our a priori hypotheses, we report one-tailed p values when comparing stimuli (previously) associated with reward or aversive outcome versus neutral stimuli, and two-tailed p values when directly comparing stimuli (previously) associated with reward and aversive outcome.

Liquid Rating

Pleasantness ratings for the reward solution (M = 8.11, SD = 1.46) and salt solution (M = 1.55, SD = 1.08) at the beginning of the experiment were significantly different from the neutral score "5," ts > 15.34, ps < .001.

Decision-Making Task

For each combination of reward and salt solution amounts, we computed the difference between the two amounts (i.e., reward solution amount − salt solution amount), resulting in 10 differential scores, ranging from −0.9 to 0.9. Positive scores indicate higher amount of reward solution on a given trial. There was a significant linear trend with respect to the probability of placing a bet, $F(1, 51) = 1223.66$, $p < .001$, $\eta_p^2 = 0.96$, suggesting that participants were more likely to place a bet the higher the amount of reward solution relative to the amount of salt solution (Figure 2). The average amount of reward and salt solutions used for the training phase was 0.6 ml ($SD = 0.18$) and 0.5 ml ($SD = 0.18$), respectively.

Training Phase

RTs and accuracy from the training phase were subjected to a repeated-measures analysis of variance with target type (reward, salt, and neutral) as a factor. There was no significant effect, both for RTs (*M*s = 243 ms for reward, salt, and neutral) and accuracy (*M*s = 97.3%, 96.3%, and 96.8% for reward, salt, and neutral, respectively), all *F*s < 2.24, all *p*s > .09.

Posttraining pleasantness ratings for the reward solution ($M = 7.96$, $SD = 1.55$) did not significantly differ from the initial rating, $t(41) = 0.67$, $p = .51$. However, the salt solution ($M = 0.82$, $SD = 0.96$) was perceived as more unpleasant, $t(41) = 3.62$, $p < .001$, $d = 0.56$, 95% CI [0.27, 0.97].[1]

Test Phase

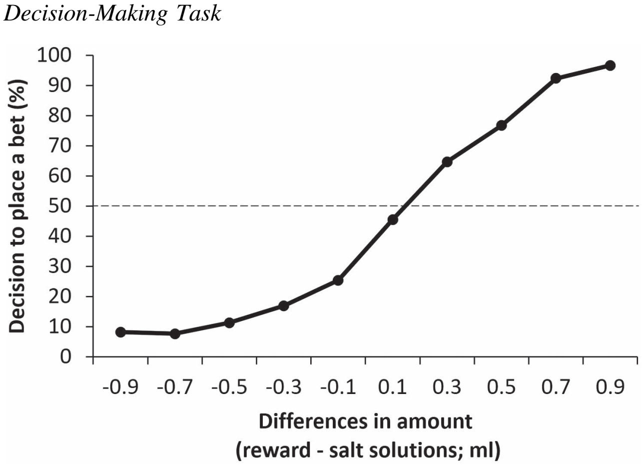
Given our a priori hypotheses, RTs and error rates from the test phase were subjected to paired-samples *t* tests. We first compared the reward- and salt-predictive stimuli with the neutral stimulus. RT was slower when there was a salt distractor and neutral target relative to when there was a salt target and neutral distractor, $t(51) = 2.03$, $p = .02$, $d = 0.28$, 95% CI [0.00007, 0.0136], suggesting that attention was biased in favor of the color associated with salt. RT was marginally slower when there was a reward distractor and neutral target relative to when there was a reward target and neutral distractor, $t(51) = 1.55$, $p = .06$, $d = 0.22$, 95% CI [−0.00156, 0.0121] (Figure 3, top).

Error rate was numerically higher when there was a salt distractor and neutral target relative to when there was a salt target and neutral distractor, $t(51) = 1.41$, $p = .08$. On the other hand, error rate was significantly higher when there was a reward distractor and neutral target relative to when there was a reward target and neutral distractor, $t(51) = 2.09$, $p = .02$, $d = 0.29$, 95% CI [0.00075, 0.0393], indicative of a value-driven attentional bias (Figure 3, middle). A direct comparison between reward and salt stimuli was not significant for either RT or error rate, *t*s < 0.83, *p*s > .41. These null results were corroborated by Bayesian paired-samples *t* tests, Bayes Factor (BF_{10}) < 0.21.

In order to account for the inconsistent pattern of results between reward and salt stimuli with respect to the threshold for statistical significance, inverse efficiency score [IES = RT/(1 − proportion of error)] that aggregates RT and error rate as a single dependent measure was also computed and subjected to paired-samples *t* tests. IES was higher when there was a reward distractor and neutral target compared to when there was a reward target and neutral distractor, $t(51) = 2.1$, $p = .02$, $d = 0.29$, 95% CI [0.00088, 0.0377]. IES was also higher when there was a salt distractor and neutral target compared to when there was a salt target and neutral distractor, $t(51) = 1.82$, $p = .04$, $d = 0.25$, 95% CI [−0.00223, 0.0462]. These results provide additional support for the hypothesis that valent stimuli bias attention, relative to neutral stimuli. A direct comparison was again not significant, $t(51) = 0.97$, $p = .34$, $BF_{10} = 0.24$ (Figure 3, bottom).

Figure 2

Percentage of Trials on Which a Bet Was Placed as a Function of Differences in Amounts of Reward and Salt Solutions From the Decision-Making Task



General Discussion

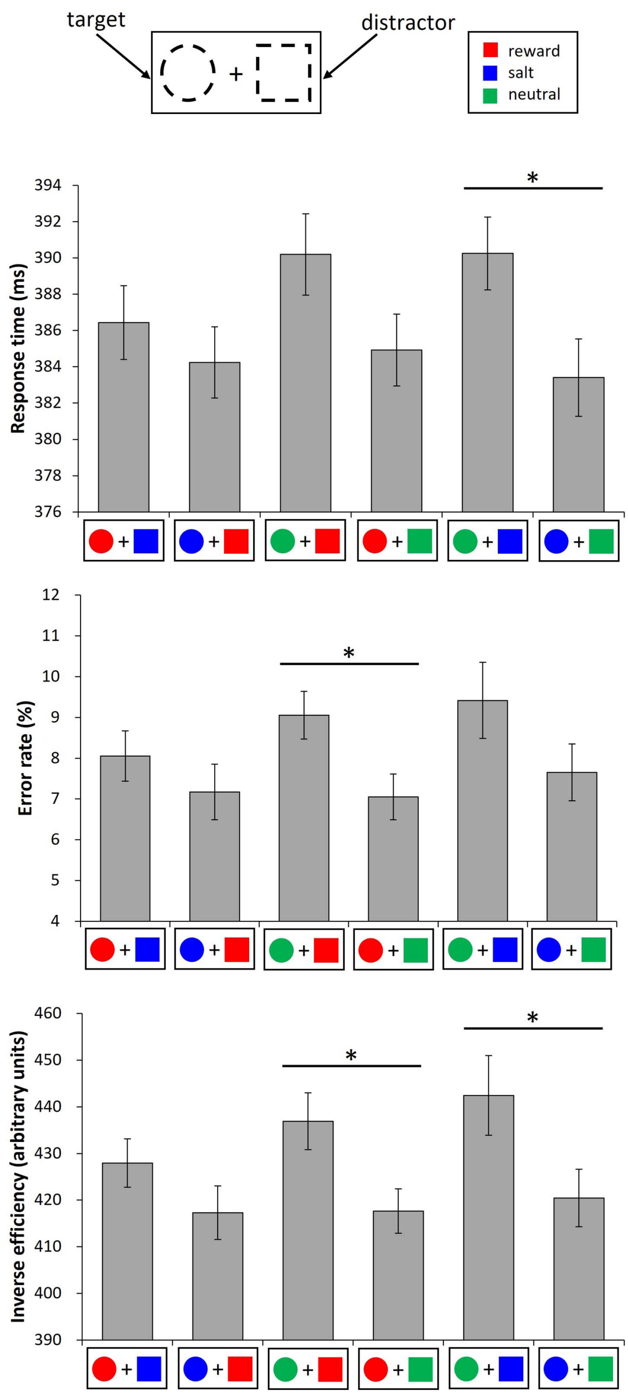
In the present study, we examined how stimuli signaling reward and aversive outcomes, matched for modality as primary reinforcers/punishers, influence attention. In doing so, we also determined the point of subjective equality in an attempt to equate the valence of the outcomes, allowing for a fairer comparison with respect to the associated magnitude of attentional bias than has been previously provided in the literature. Consistent with prior findings (e.g., Anderson et al., 2011; Kim & Anderson, 2019, 2021; Kim et al., 2021; Schmidt et al., 2015), our results revealed that stimuli predictive of primary reward and aversive outcomes bias attention and their effects are comparable, as indicated by higher error rate and slower RT. These results suggest that value- and threat-driven attention are indeed dimension-neutral (Delgado et al., 2006, 2011; Kim et al., 2011), and that affective/motivational salience or relevance-for-survival, rather than a particular valence, has a predominant influence on the allocation of attention (Gable & Harmon-Jones, 2010; Moors et al., 2013; Pool et al., 2016).

Evidence that primary and secondary reinforcers are processed in separate regions of the brain (Beck et al., 2010; Levy & Glimcher, 2011; Sescousse et al., 2010, 2013) indicates that such outcomes may exert distinct influences on behavior, complicating comparisons concerning attention to a stimulus associated with a secondary reinforcer and a stimulus associated with a primary punisher. The present study was designed to provide a straightforward comparison of attentional biases for reward and threat cues unconfounded by such differences. Our results are in line with the common currency hypothesis, which suggests that representations of different outcomes are mapped to a single valuation scale within the orbitofrontal/ventromedial prefrontal cortex (Levy & Glimcher, 2011, 2012). It is possible that the salience signal which induces value- and

[1] Posttraining pleasant ratings were collected from 42 of the participants.

Figure 3

Mean Response Times (Top), Error Rates (Middle), and Inverse Efficiency Scores (Bottom) From the Test Phase



Note. Error bars represent the within-subjects SEM. SEM = standard error of the mean. See the online article for the color version of this figure.
* $p < .05$.

threat-driven attentional bias originates from the common value representation within these regions.

In conclusion, the present study provides support for the prominence of motivational salience in experience-driven attention. Value- and threat-driven attentional capture persist even after controlling for the valence and modality of the outcomes that give rise to these biases. Importantly, the effects of these matched rewarding and aversive outcomes on attention are comparable, providing additional evidence in support of the motivational salience account. We do not see evidence that the control of attention is more strongly driven by reward than aversive outcomes or vice versa; it appears rather that stimuli previously associated with an affectively salient event (Kim et al., 2021; Lindquist et al., 2016; Moors et al., 2013; Pool et al., 2016)—whether that event be positively or negatively valanced—are prioritized by attention, to a comparable degree when the salience of the outcome is carefully matched. In using a salt solution as the aversive outcome, our findings also support the idea that the influence of aversive conditioning on the control of attention is dimension-neutral, with unpleasant gustatory experiences shaping the attention system as a primary punisher in addition to electric shock (De Tommaso et al., 2017; Pool et al., 2014). Attentional biases toward stimuli associated with aversive taste outcomes may serve to help ensure that potentially edible but unpleasant food and drink receive adequate consideration in the process of deciding what to consume, with an organism biased to "watch out" for such stimuli lest they inadvertently consume them.

References

Anderson, B. A., Kim, H., Kim, A. J., Liao, M.-R., Mrkonja, L., Clement, A., & Grégoire, L. (2021). The past, present, and future of selection history. *Neuroscience and Biobehavioral Reviews*, *130*, 326–350. https://doi.org/10.1016/j.neubiorev.2021.09.004

Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(25), 10367–10371. https://doi.org/10.1073/pnas.1104047108

Anderson, B. A., Laurent, P. A., & Yantis, S. (2014). Value-driven attentional priority signals in human basal ganglia and visual cortex. *Brain Research*, *1587*, 88–96. https://doi.org/10.1016/j.brainres.2014.08.062

Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top–down versus bottom–up attentional control: A failed theoretical dichotomy. *Trends in Cognitive Sciences*, *16*(8), 437–443. https://doi.org/10.1016/j.tics.2012.06.010

Barbaro, L., Peelen, M. V., & Hickey, C. (2017). Valence, not utility, underlies reward-driven prioritization in human vision. *Journal of Neuroscience*, *37*(43), 10438–10450. https://doi.org/10.1523/JNEUROSCI.1128-17.2017

Beck, S. M., Locke, H. S., Savine, A. C., Jimura, K., & Braver, T. S. (2010). Primary and secondary rewards differentially modulate neural activity dynamics during working memory. *PLOS ONE*, *5*(2), Article e9251. https://doi.org/10.1371/journal.pone.0009251

Becker, M. W., Hemsteger, S. H., Chantland, E., & Liu, T. (2020). Value-based attention capture: Differential effects of loss and gain contingencies. *Journal of Vision*, *20*(5), Article 4. https://doi.org/10.1167/jov.20.5.4

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*(4), 433–436. https://doi.org/10.1163/156856897X00357

Bucker, B., & Theeuwes, J. (2017). Pavlovian reward learning underlies value driven attentional capture. *Attention, Perception & Psychophysics*, *79*(2), 415–428. https://doi.org/10.3758/s13414-016-1241-1

De Tommaso, M., Mastropasqua, T., & Turatto, M. (2017). The salience of a reward cue can outlast reward devaluation. *Behavioral Neuroscience*, *131*(3), 226–234. https://doi.org/10.1037/bne0000193

Delgado, M. R., Jou, R. L., & Phelps, E. A. (2011). Neural systems underlying aversive conditioning in humans with primary and secondary reinforcers. *Frontiers in Neuroscience*, *5*, Article 71. https://doi.org/10.3389/fnins.2011.00071

Delgado, M. R., Labouliere, C. D., & Phelps, E. A. (2006). Fear of losing money? Aversive conditioning with secondary reinforcers. *Social Cognitive and Affective Neuroscience*, *1*(3), 250–259. https://doi.org/10.1093/scan/nsl025

Gable, P., & Harmon-Jones, E. (2010). The motivational dimensional model of affect: Implications for breadth of attention, memory, and cognitive categorisation. *Cognition and Emotion*, *24*(2), 322–337. https://doi.org/10.1080/02699930903378305

Galea, J. M., Mallia, E., Rothwell, J., & Diedrichsen, J. (2015). The dissociable effects of punishment and reward on motor learning. *Nature Neuroscience*, *18*(4), 597–602. https://doi.org/10.1038/nn.3956

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263–291. https://doi.org/10.2307/1914185

Kim, H., & Anderson, B. A. (2019). Dissociable components of experience-driven attention. *Current Biology*, *29*(5), 841–845.e2. https://doi.org/10.1016/j.cub.2019.01.030

Kim, H., & Anderson, B. A. (2021). How does the attention system learn from aversive outcomes? *Emotion*, *21*(4), 898–903. https://doi.org/10.1037/emo0000757

Kim, H., Nanavaty, N., Ahmed, H., Mathur, V. A., & Anderson, B. A. (2021). Motivational salience guides attention to valuable and threatening stimuli: Evidence from behavior and functional magnetic resonance imaging. *Journal of Cognitive Neuroscience*, *33*(12), 2440–2460. https://doi.org/10.1162/jocn_a_01769

Kim, H., Shimojo, S., & O'Doherty, J. P. (2011). Overlapping responses for the expectation of juice and money rewards in human ventromedial prefrontal cortex. *Cerebral Cortex*, *21*(4), 769–776. https://doi.org/10.1093/cercor/bhq145

Koster, E. H. W., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2004). Does imminent threat capture and hold attention? *Emotion*, *4*(3), 312–317. https://doi.org/10.1037/1528-3542.4.3.312

Kubanek, J., Snyder, L. H., & Abrams, R. A. (2015). Reward and punishment act as distinct factors in guiding behavior. *Cognition*, *139*, 154–167. https://doi.org/10.1016/j.cognition.2015.03.005

Le Pelley, M. E., Pearson, D., Griffiths, O., & Beesley, T. (2015). When goals conflict with values: Counterproductive attentional and oculomotor capture by reward-related stimuli. *Journal of Experimental Psychology: General*, *144*(1), 158–171. https://doi.org/10.1037/xge0000037

Levy, D. J., & Glimcher, P. W. (2011). Comparing apples and oranges: Using reward-specific and reward-general subjective value representation in the brain. *Journal of Neuroscience*, *31*(41), 14693–14707. https://doi.org/10.1523/JNEUROSCI.2218-11.2011

Levy, D. J., & Glimcher, P. W. (2012). The root of all value: A neural common currency for choice. *Current Opinion in Neurobiology*, *22*(6), 1027–1038. https://doi.org/10.1016/j.conb.2012.06.001

Lindquist, K. A., Satpute, A. B., Wager, T. D., Weber, J., & Barrett, L. F. (2016). The brain basis of positive and negative affect: Evidence from a meta analysis of the human neuroimaging literature. *Cerebral Cortex*, *26*(5), 1910–1922. https://doi.org/10.1093/cercor/bhv001

Moors, A., Ellsworth, P. C., Scherer, K. R., & Frijda, N. H. (2013). Appraisal theories of emotion: State of the art and future development. *Emotion Review*, *5*(2), 119–124. https://doi.org/10.1177/1754073912468165

Pool, E., Brosch, T., Delplanque, S., & Sander, D. (2014). Where is the chocolate? Rapid spatial orienting toward stimuli associated with primary rewards. *Cognition*, *130*(3), 348–359. https://doi.org/10.1016/j.cognition.2013.12.002

Pool, E., Sennwald, V., Delplanque, S., Brosch, T., & Sander, D. (2016). Measuring wanting and liking from animals to humans: A systematic review. *Neuroscience and Biobehavioral Reviews*, *63*, 124–142. https://doi.org/10.1016/j.neubiorev.2016.01.006

Schmidt, L. J., Belopolsky, A. V., & Theeuwes, J. (2015). Attentional capture by signals of threat. *Cognition and Emotion*, *29*(4), 687–694. https://doi.org/10.1080/02699931.2014.924484

Sescousse, G., Caldú, X., Segura, B., & Dreher, J.-C. (2013). Processing of primary and secondary rewards: A quantitative meta analysis and review of human functional neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, *37*(4), 681–696. https://doi.org/10.1016/j.neubiorev.2013.02.002

Sescousse, G., Redouté, J., & Dreher, J.-C. (2010). The architecture of reward value coding in the human orbitofrontal cortex. *Journal of Neuroscience*, *30*(39), 13095–13104. https://doi.org/10.1523/JNEUROSCI.3501-10.2010

Smith, S. D., Most, S. B., Newsome, L. A., & Zald, D. H. (2006). An emotion-induced attentional blink elicited by aversively conditioned stimuli. *Emotion*, *6*(3), 523–527. https://doi.org/10.1037/1528-3542.6.3.523

Wang, L., Yu, H., & Zhou, X. (2013). Interaction between value and perceptual salience in value-driven attentional capture. *Journal of Vision*, *13*(3), Article 5. https://doi.org/10.1167/13.3.5

Wentura, D., Müller, P., & Rothermund, K. (2014). Attentional capture by evaluative stimuli: Gain- and loss-connoting colors boost the additional-singleton effect. *Psychonomic Bulletin & Review*, *21*(3), 701–707. https://doi.org/10.3758/s13423-013-0531-z

Yee, D. M., Crawford, J. L., Lamichhane, B., & Braver, T. S. (2021). Dorsal anterior cingulate cortex encodes the integrated incentive motivational value of cognitive task performance. *Journal of Neuroscience*, *41*(16), 3707–3720. https://doi.org/10.1523/JNEUROSCI.2550-20.2021

Zhuang, R., Tu, Y., Wang, X., Ren, Y., & Abrams, R. A. (2021). Contributions of gains and losses to attentional capture and disengagement: Evidence from the gap paradigm. *Experimental Brain Research*, *239*(11), 3381–3395. https://doi.org/10.1007/s00221-021-06210-9

Received May 16, 2022
Revision received September 12, 2022
Accepted September 26, 2022 ■