Selective attention to real-world objects drives their emotional appraisal

Nathan J. Wispinski¹ • Shihao Lin^{2,3} • James T. Enns⁴ • Craig S. Chapman^{3,5}

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Abstract

Attentional manipulations have been shown to influence subsequent evaluations of objects and images. For example, images used as distractors in a visual search task are subsequently rated more negatively than are target images. One powerful manipulation of attention occurs when we plan and execute movements toward objects in our environment. Here, in two experiments, we show that selective attention to real-world objects subsequently improves emotional appraisal of those objects—an effect we term “target appreciation.” Participants were presented with abstract images on three-dimensional objects, and were cued to either reach and grasp one of the two objects, or to respond to the cued object with a keyboard. Images presented on target objects were appraised more positively when compared with novel images. In contrast, images associated with obstacles or distractor objects were not appraised differently than novel images, despite the attentional suppression thought to be required to successfully avoid or ignore these objects. We speculate that this automatic appreciation of the objects of selective attention may be adaptive for organisms acting in complex environments.

Keywords Selective attention · Emotion · Preferences · Motor processes · Real world

Attentional manipulations have been shown to influence affective ratings of images and objects (Fenske & Raymond, 2006; Schonberg et al., 2014; Veling, Aarts, & Stroebe, 2013). One powerful manipulation of attention occurs when we plan and execute movements toward objects in our environment. Studies of reaching and grasping show that attention is dynamically enhanced for the locations containing targets that must be approached (Baldauf, Wolf, & Deubel, 2006), and that attention is dynamically suppressed for locations containing obstacles that must be avoided (Chapman, Gallivan, Culham, & Goodale, 2011). Here, we consider the

consequences of attention enhancement and suppression for the affective evaluation of objects at those locations.

Deploying attention to an object, especially for the purposes of acting on it, generally results in an increase in the appraisal of that object (De Vito & Fenske, 2018; Krajbich, Armel, & Rangel, 2010; Schonberg et al., 2014). For example, making participants press a button when they saw a particular item later boosts the evaluation of that item (Schonberg et al., 2014). This particular effect requires a motor action associated with the image of interest, and suggests that more attention because of action to a high-valued item subsequently increases its value. Further, paying attention to something by fixating it with one’s eyes has been shown to amplify evaluations of items in the moment (Krajbich et al., 2010).

Conversely, tasks requiring one to inhibit a response toward an object generally result in a reduced evaluation of that object. One prominent example of how attentional inhibition impacts affective evaluation is in an effect known as distractor devaluation (Fenske & Raymond, 2006; Fenske, Raymond, & Kunar, 2004; Goolsby, Shapiro, & Raymond, 2009; Griffiths & Mitchell, 2008; Kiss et al., 2007; Raymond, Fenske, & Tavassoli, 2003; Raymond, Fenske, & Westoby, 2005; Veling, Holland, & van Knippenberg, 2007). Here, when the task requires one to ignore an image in order to attend to another image, the affective evaluation of the ignored image

✉ Nathan J. Wispinski
nathan3@ualberta.ca

¹ Department of Psychology, University of Alberta, P-217 Biological Sciences Building, Edmonton, Alberta T6G 2R3, Canada

² Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, AB, Canada

³ Neuroscience and Mental Health Institute, University of Alberta, Edmonton, AB, Canada

⁴ Department of Psychology, University of British Columbia, Vancouver, BC, Canada

⁵ Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, AB, Canada

is reduced relative to attended and novel images. Numerous studies of this effect have reported that distractor devaluation occurs for images of abstract art as well as for stimuli such as human faces (Fenske & Raymond, 2006). In other studies, associating food options or pictures with a no-go signal in a go/no-go task results in the subsequent devaluation of those items, presumably through suppressed attention and/or through an association with an avoidance action or response inhibition (Chen, Veling, Dijksterhuis, & Holland, 2016; Veling, Aarts, & Papies, 2011; Veling et al., 2013; Veling, Holland, & van Knippenberg, 2008).

Taken together, these studies of attentional enhancement and suppression suggest that the affective evaluation of objects in a selective attention and/or action task faithfully mirror the relative degree of attentional selection or inhibition any given object receives. Yet, very few studies have so far investigated this hypothesis in a systematic way, in order to disentangle the effects of enhancement versus suppression on the same objects, the effects of acting on an object by reaching, touching, or grasping versus merely indicating a response via a remote key press, and the effects of using real 3D objects versus screen images.

A few previous studies have examined the influence of attention on affective evaluation through the lens of movement. For example, simple physical interaction with an object improves subsequent evaluations of that object (Peck & Shu, 2009; Streicher & Estes, 2015). Further, when participants interacted with real-world objects in a fluent (vs. nonfluent) manner, they reported liking that object more (Hayes, Paul, Beuger, & Tipper, 2008). However, in this study participants only rated the target object, not the obstacle/distractor object. Other research has shown that responding with the hand that is on the same side as a graspable object increased evaluations (Cannon, Hayes, & Tipper, 2010). Even the nature of the movement made toward a target object (arm flexion vs. extension) has an influence on affective ratings, perhaps through the activation of muscles required to approach and avoid objects, respectively (Cacioppo, Priester, & Berntson, 1993). Together, these studies suggest that movements made with regard toward objects, and/or the attentional requirements of making those movements, has a significant impact on the subsequent evaluation of those objects. Here, we address two unanswered questions in this literature. First, since physical interaction has been shown to improve valuations (Peck & Shu, 2009; Streicher & Estes, 2015), it is not clear whether attention for movement or the physical interaction itself may be responsible for subsequent appreciation of stimuli. Second, while there is evidence that ratings of a target object appreciate as a result of movement-based attention, it remains to be seen whether ratings of distractor objects or obstacles are influenced in a similar manner.

On this note, there is controversy about the role of attention when avoiding a physical obstacle in our way. On the one

hand, obstacle avoidance is thought to require more cognitive resources and attention for successful action (Agyei, van der Weel, & van der Meer, 2016; Baldauf, 2018; Deubel & Schneider, 2004; Johansson, Westling, Bäckström, & Flanagan, 2001). On the other hand, obstacle avoidance may be implemented by inhibiting neural activity corresponding to obstacle locations (Howard & Tipper, 1997; Tipper, Howard, & Jackson, 1997; Welsh & Elliott, 2004). FMRI work shows that obstacle avoidance results in a suppressed signal in the area of visual cortex corresponding to the obstacle location (Chapman et al., 2011). These results make sense in an attentional landscape framework (Baldauf & Deubel, 2010), where inhibited areas of neural space are also those to physically avoid in movement space. However, the same study showed that neural activity in the intraparietal sulcus scaled with movement interference, suggesting an increased resource demand in the presence of obstacles (Chapman et al., 2011). Overall, obstacles are thought to be a special kind of nontarget/distractor when considering how they are attended and acted on. In context to the present study, if obstacles are inherently enhanced or suppressed during movement, it is possible we should see enhanced or suppressed evaluations on subsequent ratings of obstacles. This may provide further evidence as to how obstacles are attended in order to successfully complete actions.

Overall, these studies suggest that under some circumstances, attention directed to a stimulus will lead to subsequent affective appreciation, while attention withdrawn from it will cause devaluation. Because selective attention is necessarily directed to an object when reaching for or grasping it, we expect that target-associated stimuli will be subsequently appreciated, while nontargets will be suppressed and subsequently devalued. Given this framework, the current study aims to answer two questions. In Experiment 1, we investigate if appreciation and devaluation will be observed when evaluating objects that are targets, nontargets, or physical obstacles during real object interaction. In Experiment 2, we investigate if physical interaction is necessary to observe these effects.

Experiment 1

Experiment 1 tested whether the focused attention that is paid to or withdrawn from stimuli during object interaction subsequently increases or decreases subjective ratings toward those stimuli.

Participants were seated at a table with a ceiling-mounted projector, which projected stimuli onto the tabletop. On this table were two upright objects with embedded screens (5th Generation Apple iPods; see Fig. 1a). On each trial, a different type of image was presented on each of the two objects (see Fig. 1b). A cue word (*circles*, *squares*, or *shape*) was then presented on the tabletop, and participants were asked to reach

Fig. 1 Experiment methods. **a** Experiment 1 setup. Subjects interacted with two real-world objects displaying abstract images. A fixation cross, cue word, evaluation slider, and start positions were projected onto the tabletop from above. **b** Images of the type “circles,” “squares,” and “shapes” were randomly generated on every trial. **c** Example trial timelines. In Experiment 1, participants were presented two images on real objects followed by a cue word, which directed them to reach and grab the

object presenting the matching image type. After responding, participants rated either an image they saw during their response at the object it was presented on, or a novel image on one of the two objects. In Experiment 2, participants were first presented a cue word followed by two images. Participants responded either with a reach-to-grasp movement, or a key press. **d** Single-trial reach trajectories on example target–distractor and target–obstacle trials beginning with the participant’s hand on the left side

and grab the object displaying the image type that matched the cue word (see Fig. 1c). Afterward, participants were shown one image on one of the objects and were asked to affectively evaluate that image using a slider on the table.

Participants performed reach-to-grasp actions with their right hand, while their right index finger was tracked using infrared motion cameras (see Fig. 1d). Reaching movements began to the right or left of the objects on every trial. As such, when the far object matched the cued word, the close object became an obstacle to reach around, similar to other studies investigating reach-to-grasp movements with obstacles (Baldauf & Deubel, 2010; Chapman et al., 2011; Deubel & Schneider, 2004; Hayes et al., 2008).

Critically, images that could be affectively evaluated were either the target-related image on that trial, the nontarget-related image on that trial, or an image of the third type not presented on that trial. For example, if cued to reach toward a “shape” image over a “circles” image (as in Fig. 1c), one could be subsequently asked to evaluate either the “shape,” “circles,” or a novel “squares” image not shown on that trial. Further, while images were of three types used in past research (Raymond et al., 2003), each image was randomly generated on each trial, so no exact image was presented on more than one trial (see Open Practices).

An important design choice in Experiment 1 was to either present many different images on two static objects, or to choose among many objects on each trial (as in Masson, Bub, & Newton-Taylor, 2008; Snow et al., 2011; Styrkowiec, Nowik, & Króliczak, 2019). Because we did not want participants to rate the same handful of objects multiple times, we opted to present a wide variety of unique images on two unchanging objects.

Methods

Experiment 1 was preregistered (osf.io/iyd9s) under the hypothesis that obstacles would be particularly devalued, as fMRI data suggests obstacles are attentionally inhibited relative to targets and even distractors (Chapman et al., 2011). Relative to preregistration, the intended sample size was doubled, and exclusion criteria were loosened, as our focus shifted from reach-dependent measures (e.g., $n = 40$, as recommended by Gallivan & Chapman, 2014) to evaluation dependent measures (e.g., $n = 80$, as reported in Raymond et al., 2003).

Participants

Eighty-two participants (50 women; age: $M = 20.96$ years, $SD = 4.40$ years) took part in Experiment 1. All participants gave written consent prior to the experiment, which was approved by the University of British Columbia’s Behavioural Research Ethics Board. All participants were right-handed, had normal or corrected-to-normal vision, and did not know the purpose of the study. Participants were compensated with course credit.

Apparatus and stimuli

Participants’ movements were recorded at 60 Hz using six Optitrak V100:R2 cameras (NaturalPoint, Inc., Corvallis, Oregon) mounted on three tripods, which tracked one passive, reflective motion-tracking marker placed near the tip of each participant’s right index finger (see Fig. 1a). Fixation crosses, cue words, evaluation sliders, and start positions were presented at 60 Hz (synchronized with the motion capture rate) using

a ceiling-mounted projector (DELL M410HD) onto a white table, which produced an image of roughly 90 cm by 70 cm. The position of the finger marker was coregistered in space with the projected image so the tabletop could be used as a touch-interactive surface. Images were presented on two wireless screens (5th Generation iPod Touch) using third-party screen-sharing software. These screens were mounted to stand upright by themselves using Lego cases. Stimuli presentation and data collection were controlled with MATLAB using Psychtoolbox (Kleiner et al., 2007).

Design and procedure

In Experiment 1, participants were seated at a table in front of two objects with embedded screens. To start each trial, the participants placed their right index finger in the central start circle projected 5 cm forward from the front edge of the table. When the central start circle turned green, a second start circle appeared 20 cm forward from the first start circle and 30 cm to the left or right of midline. Once participants moved their right index finger to this second start circle, this circle turned green as well. Abstract images were then presented on each of the two object screens, which were placed in line with the left and right start positions and 10 cm to the left and right of midline (see Fig. 1c). After 1,500–1,700 ms (random and uniformly distributed), a cue word (*circles*, *squares*, or *shape*) was presented for 200 ms at midline between the two objects coincident with an auditory go signal. Participants then reached and grabbed the object presenting the type of image matching the cue word.

Once participants had grasped the correct object, images on both objects were then briefly replaced with question marks while the participant returned their right index finger to the central start position. Then only one image was presented on one of the objects. A horizontal line (~35 cm in length) in front of the participant then appeared with the text (“How cheerful?”; Raymond et al., 2003), with a negative sign placed on the leftmost edge of the line and a positive sign on the rightmost edge. Participants were then asked to move a slider along the line to indicate their affective rating of the presented image, and confirmed their rating by returning to the central home position to start another trial.

Abstract stimuli consisted of three types adapted from Raymond et al. (2003): circles, squares, and shapes (see Fig. 1b). Circles consisted of random dots varying in color, number, and position; squares consisted of a 5×5 grid of varying colors; and shapes consisted of a single polygon that varied in its color and number of vertices. All stimuli were randomly generated on every trial (code publicly available; see Open Practices).

Participants completed 10 practice trials, followed by 6 blocks of 48 trials (298 total). The start side of the hand (left/right), side of the cued object (left/right), object on which

subsequent evaluation would take place (left/right), and whether the evaluation image appeared on that object during the reaching movement or was of the third class of image unused on that trial (seen/novel) were counterbalanced across the experiment. As such, there were 16 unique experimental conditions, which were each repeated 18 times throughout the experiment (288 total).

Images presented on the cued object during action were classified as targets (see Fig. 1d). Images presented on the noncued object during action were classified as either distractors or obstacles, depending if the participant needed to reach around the noncued object to grasp the cued object. Images were classified as novel if they were of the third type of image not present during the reach-to-grasp action on the trial.

Data analyses

Trials on which participants received an error message online were not analyzed (i.e., when movements were initiated before the go signal, when reaction time was >2 s, when movement time was >2 s, or when they grabbed the incorrect target). Trials were also rejected offline if they contained motion capture recording errors, affective evaluation recording errors, or long movement or reaction times (>2 SD above participant’s own mean). Practice trials (first block of 10 trials) were also not included. To preserve statistical power for all participants in all conditions, we rejected participants with fewer than 50% usable trials after trial rejection in general, or in any of the unique conditions (16 unique conditions in Experiment 1). These exclusions left 71 participants for analysis, with an average of 246 usable trials (83% of total) per participant in Experiment 1. All statistical tests are Greenhouse–Geisser and Bonferroni corrected where applicable. Excluding all other errors, participants grasped the correct object over the incorrect object on the vast majority of trials ($M = 98.81\%$; range: 91.67%–100%).

Results

Evaluation ratings were analyzed in four conditions: target = participants evaluated the abstract stimulus presented on the object they interacted with; distractor = participants evaluated the abstract stimulus presented on the object they did not interact with *and* that object did not obstruct the path to the target; obstacle = participants evaluated the abstract stimulus presented on the object they did not interact with *and* that object obstructed the path to the target; novel = participants evaluated an abstract stimulus they had not seen during that trial. A one-way repeated-measures analysis of variance (ANOVA) showed that evaluation responses differed significantly among these four conditions, $F(2.65, 185.75) = 3.31$, $p = .026$, $\eta_p^2 = .0038$. Multiple comparisons show that only

target-associated images were elevated significantly, relative to the baseline evaluation of novel images not shown during the reaching part of the trial, $t(70) = 2.96$, $p = .0042$, Cohen's $d = 0.17$. Images presented on obstacles or distractors during movement were not rated either significantly more positive or negative than novel images (see Fig. 2a). For completeness, Bonferroni-corrected multiple comparisons did not show any significant differences between target-associated, distractor-associated, or obstacle-associated images, $p_s > .0083$. Following Experiment 2, we combined the data from both experiments to show that it was the target-associated images, and not the target object, that was subsequently appreciated (see Full-Factor Tests section in Experiment 2 results).

Discussion

Experiment 1 investigated whether appreciation and devaluation would be observed when evaluating images associated with objects that were targets, nontargets, or physical obstacles during real object interaction. The results showed clear evidence for target appreciation—unique, abstract stimuli were rated as more pleasing if they were presented on the selected real-world object during action, relative to novel abstract stimuli presented just after an action.

There are several reasons why images presented on targets during action might be enhanced relative to novel images, or those associated with distractors or obstacles. Target selection requires significant attention, especially in grasping tasks (Baldauf & Deubel, 2010), which may have enhanced the subsequent evaluation of associated images, similar to other effects of attention on value (Krajbich et al., 2010; Schonberg et al., 2014). This is consistent with the idea that the degree of attention paid to a stimulus will have an impact on subsequent affective appraisals.

Experiment 1 revealed no evidence that affective ratings for obstacles differed from a baseline of novel images. Some have argued that obstacles are a special kind of distractor that require more attention than other nontargets (Aggei et al., 2016; Baldauf, 2018; Deubel & Schneider, 2004; Johansson et al., 2001) or less attention than other nontargets (Baldauf & Deubel, 2010; Chapman et al., 2011; Howard & Tipper, 1997; Tipper et al., 1997; Welsh & Elliott, 2004). As such, we expected but did not find devaluation of affective ratings for obstacles following an action. We also did not find any devaluation of distractor-associated images.

The absence of devaluation in Experiment 1 may be attributed to the lack of visual interference between targets, and obstacles or distractors. For instance, in the distractor devaluation literature, distractor images must be relatively close (~2 cm) to target images to cause subsequent devaluation (De Vito, Al-Aidroos, & Fenske, 2017; Martiny-Huenger, Gollwitzer, & Oettingen, 2014; Raymond et al., 2005). In Experiment 1, while obstacles certainly interfered with movement trajectories en route to targets (see Fig. 1d), the two objects were placed 10 cm away from each other, reducing interference potential. While the lack of interference is certainly a valid explanation for the potential lack of devaluation effects observed in Experiment 1, investigating this issue further proves to be methodologically difficult; placing obstacles and target objects ~2 cm from one another requires very different kinds of reaching movements outside the scope of this study.

Further, in Experiment 1, both images were first presented before the cue word that determined which image was the target on that trial. Perhaps attending both images without knowing which was the target enhanced both images, regardless of whether they were a target or obstacle/distractor in the future. This idea is consistent with aspects of an attentional landscape framework (Baldauf & Deubel, 2010), where

Fig. 2 Affective evaluation ratings of abstract images following attentional manipulations. **a** Experiment 1 showing target appreciation after reaching to real objects. **b** Experiment 2 ratings after reaching

responses. **c** Experiment 2 ratings after keyboard responses. Error bars are 95% CI of within-subjects standard error; y-axis is shortened for visibility. * $p < .0083$ compared to Novel baseline

attending both images/objects as potential targets for an extended period of time may have enhanced them, potentially altering subsequent appreciation or devaluation. This presentation order may explain why obstacles and distractors were not devalued in Experiment 1. One way to address this concern is to change the presentation order of the images and cue word. If the cue word is presented first, then participants will already know which image is the target and which is the non-target on that trial. This presentation order would limit attentional enhancement time pre-movement, and perhaps allow for more attentional suppression and subsequent devaluation (Baldauf & Deubel, 2010; Chapman et al., 2011). This was one of the methodological changes made in Experiment 2.

As stated before, physical interaction with objects has been found to increase affective ratings of real-world objects (Peck & Shu, 2009; Streicher & Estes, 2015). In Experiment 1, participants only physically grabbed target objects. Therefore, the target appreciation found in Experiment 1 may be due solely to physical interaction with the target objects that hold the images. However, physical interaction with objects is difficult to disentangle from the attention paid to targets in reaching and grasping studies. One way to investigate whether physical touch is necessary for target appreciation is by conducting a similar experiment where participants are acting on objects, but not interacting with them (e.g., with a key press). The main goal of Experiment 2 was to compare subjective evaluations following keyboard responses with the evaluations made following reaching responses in Experiment 1.

Experiment 2

We next tested whether physical interaction with objects is necessary to observe the target appreciation effect found in Experiment 1. Specifically, in Experiment 2 (see Fig. 1c), participants completed the same task in two conditions. In one condition, responses were made by reaching to grasp the real-world object, as in Experiment 1. In the other condition participants pressed a left or right key on a keyboard to indicate which real-world object matched the cue word. Further, participants were first shown the cue word (*circles*, *squares*, or *shape*), and then the two images on each of the objects were presented, rather than the reverse order, as in Experiment 1.

Methods

Sixty-nine participants (39 women; age: $M = 19.39$ years, $SD = 1.72$ years) took part in Experiment 2 to as closely match our Experiment 1 sample size as resources would allow. All participants gave written consent prior to the experiment, which was approved by the University of Alberta's Research Ethics Office. All participants were right-handed, had normal or corrected-to-normal vision, and did not know the purpose of

the study. Participants were compensated with course credit. In Experiment 2, all participants were intended to complete both conditions; however, three subjects participated in the reach condition but not the keyboard condition, while three subjects participated in the keyboard but not reach condition. All methods for Experiment 2 are the same as in Experiment 1, with the following exceptions.

In Experiment 2, the ceiling-mounted projector was replaced with a flat-screen TV (LG 50LB6000) horizontally mounted under glass in a table. Further, stimuli presented on the object screens (iPods) were transmitted over a wired connection to improve consistency in experimental timing. In the keyboard condition in Experiment 2, participants responded using a compact, wired USB computer keyboard. Keys used for the experiment were covered in white tape for identifiability: lower left and right corner keys for responding, and entire second top line of 15 keys for affective ratings. All other keys were masked by black tape.

In Experiment 2, participants completed the same task twice, and each time were directed to respond using either a reach-to-grasp movement (as in Experiment 1) or a key press (order counterbalanced). The cue word was presented for 200 ms coincident with a beep, was then removed for 50 ms, before both images were presented on the objects (see Fig. 1c). In the keyboard condition, participants evaluated images using one row of 15 keys on a keyboard. During evaluation, a positive and negative sign were projected on each side of the ratings keys on the keyboard.

To preserve statistical power for all participants in all conditions, we rejected participants with fewer than 50% usable trials after trial rejection in general, or in any of the unique conditions (16 unique conditions in Experiment 2 reaching, and eight conditions in Experiment 2 keyboard). In Experiment 2, exclusions left 57 participants with an average of 243 usable trials per participant in the reaching condition, and 63 participants with an average of 258 trials per participant in the keyboard condition. Excluding all other errors, participants grasped the correct object over the incorrect object on the vast majority of trials in the reaching condition ($M = 96.99\%$; range: 84.77%–100%), and likewise pressed the correct key over the incorrect key on the vast majority of trials in the keyboard condition ($M = 95.67\%$; range: 84.43%–99.63%).

Results

We again ask if attention to real-world objects on a trial influenced the affective evaluation of an associated image. For trials where participants responded with a reaching movement, a one-way repeated-measures ANOVA on attentional condition (target, distractor, obstacle, and novel) revealed that these abstract images were again evaluated differently depending on their associated attentional condition, $F(2.44,$

136.56) = 4.49, $p = .0083$, $\eta_p^2 = .0042$. Multiple comparisons showed that only target-associated images were found to be different relative to a baseline evaluation of novel images not shown during a trial, $t(56) = 3.43$, $p = .0011$, Cohen's $d = 0.12$. For trials where participants responded with a key press, abstract images were also evaluated differently depending on their attentional condition; one-way ANOVA on attentional condition (target, distractor, and novel), $F(1.49, 92.40) = 6.53$, $p = .0052$, $\eta_p^2 = .0032$. Similar to the reaching condition, when responding with a keyboard only target appreciation relative to baseline was found, $t(62) = 3.31$, $p = .0015$, Cohen's $d = 0.12$. For completeness, Bonferroni-corrected multiple comparisons showed that target images were rated as more cheerful than distractor images in the Experiment 2 reaching condition, $t(56) = 3.4117$, $p = 0.0012$. Otherwise, target-associated, distractor-associated, and obstacle-associated images were not significantly different from one another in the reaching or keyboard conditions, $ps > .0083$. Overall, target appreciation was found both when participants responded with a reach-to-grasp movement and when responding with a key press, ruling out the possibility that physical interaction with the objects was responsible for the effect (see Fig. 2c). Further, despite changes in experiment timing, equipment, and sample, the target appreciation effect from Experiment 1 was replicated.

Full-factor tests

Our experimental design permits an even more rigorous test of the affective impact of attention to real-world objects when all the factors that were manipulated are considered. For these more complete analyses, we conducted two additional ANOVAs. Recall that the category labels for the above analyses (target, distractor, obstacle, and novel) are derived from a combination of four factors in all: Start Side (hand start position, Left or Right); Evaluation Side (the side the evaluated abstract stimulus was presented on, Left or Right); Old or New (whether the evaluated abstract stimulus had been seen on that trial or not); and Target or Nontarget (whether the evaluated abstract stimulus was presented at the location you selected or not).

Examining all four factors simultaneously, we first analyzed all of the evaluations made in this study when participants were making reach responses. This meant taking all of the trials from Experiment 1 ($n = 71$) and combining them with all of the reach trials from Experiment 2 ($n = 57$). Experiment was a between-subjects factor. This resulted in a five-factor ($2 \times 2 \times 2 \times 2 \times 2$) mixed-model ANOVA, with the between-subjects factor Experiment and the within-subjects factors Start Side, Evaluation Side, Old or New, and Target or Nontarget. This analysis revealed main effects of Evaluation Side, $F(1, 126) = 56.56$, $p = 8.97 \text{ e-}12$, Target or Nontarget, $F(1, 126) = 9.70$, $p = .0023$, and Old or New, $F(1,$

126) = 13.66, $p = .00033$, as well as interactions between Experiment and Evaluation Side, $F(1, 126) = 10.34$, $p = .0017$, and Target or Nontarget and Old or New, $F(1, 126) = 6.09$, $p = .015$.

The Evaluation Side main effect was driven by objects on the Right being generally evaluated more positively (55.29%) than objects on the Left (53.08%). The interaction with Experiment was driven by the fact that this Right > Left evaluation difference was larger for the participants in Experiment 2 (Right: 55.16%, Left: 52.01%) than Experiment 1 (Right: 55.42%, Left: 54.16%), but still significant for each Experiment group in isolation (Experiment 1, $p < .0013$; Experiment 2, $p < 1.07 \text{ e-}10$). These results are consistent with previous findings showing that real-world objects presented to the right side of right-handers are attended more rapidly than objects presented to the left side, presumably because right-sided objects are privileged for manual reaching and grasping in a majority of participants (Cavallo, Ansuini, Capozzi, Tversky, & Becchio, 2017; Furlanetto, Gallace, Ansuini, & Becchio, 2014). The present findings extend this result to the realm of affective evaluations; objects privileged for reaching are also privileged when making affective judgments.

The Target or Nontarget main effect was driven by abstract stimuli presented at Target locations (54.55%) being evaluated more positively than those presented at Nontarget locations (53.83%). The Old or New main effect was driven by Old abstract stimuli seen on that trial (i.e., present during action and evaluation; 54.61%) being evaluated more positively than New stimuli that had not been seen (i.e., present during only evaluation; 53.77%). Both of these results are consistent with increased visual attention to an object being associated with increased evaluations. The critical interaction between Target or Nontarget and Old or New confirms the findings reported in the main one-way ANOVA analyses. Specifically, Old targets (55.25%) were evaluated significantly higher than New targets (53.85%) when they were presented at the Target locations ($p = 7.60 \text{ e-}5$), but there were no significant differences between the evaluation of Old (53.97%) versus New (53.67%) targets when they were presented at Nontarget locations ($p = .33$). This means that stimuli that were physically interacted with (Old stimuli at Target locations) also received a boost in positive evaluation, which we refer to as a target appreciation effect.

A second full-factor repeated-measures ANOVA directly compared the reaching versus keyboard trials in Experiment 2. The following analysis was therefore conducted on the 53 participants from Experiment 2 who completed both the reach and keyboard trials. Since the keyboard trials did not have a Start Side, we removed that as a factor for this analysis, resulting in a four-factor ($2 \times 2 \times 2 \times 2$) repeated-measures ANOVA, with Reach or Keyboard, Evaluation Side (Left or Right), Old or New, and Target or Nontarget as within-subjects factors. This analysis revealed main effects of

Evaluation Side, $F(1, 52) = 48.91$, $p = 5.06 \times 10^{-9}$, Old or New, $F(1, 52) = 10.86$, $p = .0018$, and Target or Nontarget, $F(1, 52) = 7.75$, $p = .0075$, as well as an interaction between Target or Nontarget and Old or New, $F(1, 52) = 4.06$, $p = .049$. As before, abstract stimuli evaluated on the Right (55.68%) were rated as being more positive than those on the Left (52.37%), abstract stimuli presented at Target locations (54.41%) were rated as being more positive than those presented at Nontarget locations (53.64%), and Old stimuli (54.48%) were rated as more positive than New stimuli (53.57%). Again, in this second analysis, objects privileged for reaching were also privileged when making affective judgments. That is, images presented on real-world objects on the right side of these right-handed participants are affectively appreciated.

Critically, the interaction between Target or Nontarget and Old or New again confirms that attention directed to objects enhances their affective evaluations. We find a target appreciation effect, such that Old targets (55.14%) were evaluated significantly higher than New targets (53.67%) when they were presented at the Target location ($p = .0014$), but Old (53.82%) versus New (53.47%) targets were not significantly different when they were presented at Nontarget locations ($p = .32$). This means that it is the specific images, and not the objects that were appreciated as a result of target selection. In other words, if the object was briefly appreciated, then both Old and New images presented on a target object should be subsequently appreciated. Instead, we only see that Old (i.e., Target) images were appreciated, and not New (i.e., Novel) images.

Discussion

Experiment 2 investigated whether physical interaction with objects is necessary to observe the target appreciation effect found in Experiment 1. Here, we found target appreciation both when participants responded with a reach-to-grasp movement and when participants responded with a key press. These results rule out the possibility that the appreciation of target-associated images is solely due to the appreciation of objects after physical interaction (as in Peck & Shu, 2009; Streicher & Estes, 2015), since target appreciation also occurred when participants responded remotely using a key press.

In Experiment 1, images were presented before the cue word, while in Experiment 2 the cue word was presented before the images. Results from Experiment 1 may have been influenced by the relatively long viewing time of stimuli before the cue word, which determined the target and nontarget images/objects. In an attentional landscape framework (Baldauf & Deubel, 2010), attending both images/objects as potential targets may have enhanced them, potentially altering subsequent appreciation or devaluation. However, in Experiment 2, participants only saw the images after they are given information about which one is the target and which

one is the nontarget on that trial. This was intended to limit any premovement attentional enhancement for the images in Experiment 2. Yet both experiments showed the same pattern of results—target appreciation, and no effects of obstacle-associated or distractor-associated images. Together, these results rule out the possibility that presentation order affected the results, and that viewing the images before a response was cued influenced affective ratings.

Neither of the present reaching experiments showed the fluency result observed in Hayes et al. (2008), where targets were evaluated more positively when paired with distractors relative to when they were paired with obstacles (see full repeated-measures ANOVA in Experiment 2 Results). One key difference is our use of short and sturdy screens as graspable objects, whereas Hayes et al. (2008) used a tall vase filled with water as an obstacle. Even though movement trajectories were significantly altered in our obstacle conditions (see Fig. 1d), these nonfluent actions did not impact affective ratings. One explanation for this difference in results is that it is not the fluency of an action that impacts affective evaluations, but perhaps the perceived risk associated with those actions. More research on this topic is certainly needed.

Both Experiment 1 and Experiment 2 are limited by the image presentation latency of the screens on the objects. Our experimental setup did not always allow both images to be presented on the object screens simultaneously. However, trials in both experiments were counterbalanced so that all conditions appeared on the left and right object screens in equal proportions. If, for example, one object screen was slightly faster than the other, and image order impacted affective ratings, then this difference would equally impact all conditions. There is always the possibility of an interaction between presentation latency and affective ratings however. For example, when targets are presented first, they are enhanced, but when nontargets are presented first, they are not enhanced. Such an interaction is not possible to address in the current data set.

The full-factor repeated-measures ANOVA analyses in both experiments indicated that more positive evaluations were given to images on the right side of space. While outside the scope of the current study, these findings are consistent with a large literature on stronger attention in right-handed participants to rightward stimuli both in keyboard and reaching based tasks (Kinsbourne, 1987; Lloyd, Azañón, & Poliakoff, 2010; Wispinski, Truong, Handy, & Chapman, 2017), and laterality effects in stimulus evaluation (Compton, Williamson, Murphy, & Heller, 2002; Goolsby et al., 2009). The present results are also consistent with an embodiment account, as responding with the same hand as a graspable object on a screen increased measures of emotional liking (Cannon et al., 2010). Even when not acting on an object, as in the Experiment 2 keyboard condition, the affordances of nearby graspable objects may have enhanced

cognitive processing toward those objects and their associated images (Garrido-Vásquez & Schubö, 2014; Gibson, 1979).

Conclusions

Experiment 1 investigated whether appreciation and devaluation would be observed when evaluating objects that are targets, nontargets, or physical obstacles during real object interaction. Experiment 2 investigated whether physical interaction with objects was even necessary to observe subsequent effects on affective evaluations. Overall, despite several experimental changes between Experiments 1 and 2, we found that unique images presented on target objects during a selective attentional task were affectively appreciated. We speculate that target appreciation is explained by the automatic deployment of attention toward real objects that are being selected and acted on. This result adds to a growing number of studies exploring how responding to an image or object can dramatically enhance its subsequent affective evaluation. Similar to explanations for a distractor devaluation effect (Fenske & Raymond, 2006), we speculate that the target appreciation of real objects may have important adaptive functions. We interpret the biasing of behavior toward previously selected objects through positive emotional attribution as a possible mechanism to promote the repetition of previously advantageous behavior. Other research has shown that valuable stimuli automatically capture attention (Anderson, Laurent, & Yantis, 2011; Chapman, Gallivan, Wong, Wispinski, & Enns, 2015), and so increasing the subjective value of these previously attended target objects may give these objects priority in subsequent neural processing.

These results also highlight the bidirectional entanglement of selective attention and subjective value. There is now a very large literature documenting that recently rewarded objects and object properties involuntarily draw focused spatial attention to the locations in which they occur (Anderson, 2016; Chelazzi, Perlato, Santandrea, & Della Libera, 2013; Failing & Theeuwes, 2018). The present findings help to emphasize that the arrow of influence runs in the other direction as well. Merely attending to an object in preparation of its selection for action serves to increase its subsequent emotional appraisal.

These results are similar to a cue-approach effect, where repeated button presses to a stimulus increases the subsequent evaluation of that stimulus (Schonberg et al., 2014). This cue-approach effect is also thought to impact evaluations through associations to motor-driven attention—in that task, a button press. However, the target appreciation observed in the current study does not require several stimulus–response repetitions for appreciation as in cue-approach experiments (Schonberg et al., 2014). More research is needed to investigate the conditions under which attention paid to images or objects subsequently enhances affective evaluations.

In contrast, we did not see any devaluation in any of the experiments reported here relative to novel images. In particular, obstacles were not different from baseline in any of the experiments. As stated before, on one hand, obstacle avoidance is thought to require more cognitive resources and attention for successful action (Agyei et al., 2016; Baldauf, 2018; Deubel & Schneider, 2004; Johansson et al., 2001). Alternatively, obstacle avoidance may be implemented by inhibiting neural activity corresponding to obstacle locations (Howard & Tipper, 1997; Tipper et al., 1997; Welsh & Elliott, 2004). Such accounts predict that obstacles should have been appreciated or devalued, respectively. Why was neither effect observed? Obstacles are thought to first be attended and then rapidly suppressed within an attentional landscape framework (Chapman et al., 2011). Perhaps the time course of attention with respect to emotion matters. In other words, it is possible that the influence of attention on affective evaluations in the current task happens when obstacles are in a relatively neutral position within a rapidly evolving attentional landscape (Wispinski et al., 2018). On the other hand, perhaps the effect of attention on emotion is truly asymmetrical. Additional research regarding the attentional status of obstacles before and during avoidance movements is needed.

On another hand, perhaps salient action outcomes are needed for subsequent affective tags. Successful grasping of, or button pressing toward, a target object may provide significant cues for subsequent affective appreciation. In contrast, perhaps a salient event such as obstacle collision (Hayes et al., 2008), or the misidentification of a distractor as a target, may be needed for subsequent devaluation. The fluency of such obstacle avoidance movements have been shown to drive subsequent changes in evaluations (Hayes et al., 2008). However, such events are difficult to experimentally control. Future research on these questions are needed for a complete understanding of attention-emotion mechanisms.

Experiment 2 showed that physical interaction is not needed to observe target appreciation. Of note, the effect sizes for target appreciation when responding with a reach-to-grasp movement and when responding with a key press are roughly the same. These results stand in contrast to studies showing that physical interaction with graspable objects causes subsequent appreciation (Peck & Shu, 2009; Streicher & Estes, 2015). However, both of these studies were brand and consumer product oriented, and so perhaps the context of subsequent evaluations is critical when determining if physical interaction is important.

Here we used graspable objects, but only changed the images presented on these objects in order to present hundreds of unique stimuli to participants. Perhaps to observe devaluation effects, objects themselves must change (as in Hayes et al., 2008; Masson et al., 2008; Snow et al., 2011; Styrkowiec et al., 2019). In the current study, we show that an image associated with a target becomes affectively enhanced, but

that the object itself does not (see target-old vs. target-new conditions in full-factor ANOVAs). Perhaps if the object screen was not presenting many different stimuli, the emotional tagging would be to the real-world graspable object and not the image. Given the current data, we cannot analyze whether the target-associated image presented at the location of a distractor/obstacle would still be affectively enhanced. In contrast to other studies using computer monitors, our screens were made up of graspable objects, which have strong affordances (Gibson, 1979). These affordances may have altered or enhanced processing relative to nongrasbable screens (Garrido-Vásquez & Schubö, 2014; Gibson, 1979). However, affordances are also complex—behavioral and neural studies demonstrate differential processing of two-dimensional and three-dimensional stimuli (Andersen & Kramer, 1993; He & Nakayama, 1995; Snow et al., 2011; Snow, Skiba, Coleman, & Berryhill, 2014). Perhaps future work can investigate the subsequent affective influence of avoiding two-dimensional obstacles en route to two-dimensional targets on a screen using mouse tracking.

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Author contributions N. J. Wispinski, J. T. Enns., and C. S. Chapman designed the experiment. N. J. Wispinski, S. Lin, and C. S. Chapman analyzed data. All authors interpreted data and drafted the manuscript.

Compliance with ethical standards

Declaration of conflicting interests The authors declare no competing financial interests.

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Open practices Data, materials, and analysis code have been made publicly available via the Open Science Framework and can be accessed (osf.io/iyd9s/). The design and analysis plans for Experiment 1 were preregistered (osf.io/xds96/).

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