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Reward grabs the eye: Oculomotor capture by rewarding stimuli

Jan Theeuwes *, Artem V. Belopolsky

Vrije Universiteit, Amsterdam, The Netherlands

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ABSTRACT

It is well known that salient yet task irrelevant stimuli may capture our eyes independent of our goals and intentions. The present study shows that a task-irrelevant stimulus that is previously associated with high monetary reward captures the eyes much stronger than that very same stimulus when previously associated with low monetary reward. We conclude that reward changes the salience of a stimulus such that a stimulus that is associated with high reward becomes more pertinent and therefore captures the eyes above and beyond its physical salience. Because the stimulus capture the eyes and disrupts goal-directed behavior we argue that this effect is automatic not driven by strategic, top-down control.

1. Introduction

In everyday life, our behavior is guided by visual input. The visual world consists of many objects and selective attention determines which object receives priority and which objects are ignored. Selection may be voluntary and goal directed or may be determined by the properties of the stimulus features in the environment in an automatic, bottom-up way (for a recent review see Theeuwes, 2010a). If objects receive priority of processing independent of the volitional top-down goals of the observer, one refers to this as attentional capture (Theeuwes, 1992, 2010a).

One account put forward by Theeuwes (1991, 1992, 2010a) is that initial selection is basically stimulus-driven arguing that the bottom-up salience signals of the stimuli in the visual field determines the order in which the objects are selected. According to this notion independent of the task set of the observer, the salience of the objects present in the visual field drives selection. Several computational models have stressed the role of salience in attentional selection (Itti & Koch, 2001; Itti, Koch, & Niebur, 1998). These models basically take as input an image and process the image in parallel across various feature channels using different spatial scales. The end result is a set of topographic feature maps which are then combined into a saliency map (Koch & Ullman, 1985).

Theeuwes came to the conclusion that initial selection is basically stimulus-driven on the basis of the results of his additional singleton task (Theeuwes, 1991, 1992), in which observers search for one specific clearly defined salient target singleton. Simultaneously with this target singleton, another irrelevant distractor singleton was also present. Theeuwes (1991, 1992, 1994, 2010a) has shown that the presence of this irrelevant distractor singleton slowed search for the target singleton. The increase in the time to find the target when the irrelevant singleton was present was explained in terms of attentional capture. Because the irrelevant singleton was selected even though observers were instructed to look for the target singleton, it was argued that the irrelevant singleton summoned attention exogenously to its location. This erroneous capture of attention caused an increase in the time to find the target. It is important to note that the irrelevant singleton only caused an RT increase when it was more salient than the target. When the color distractor was made less salient its presence did not affect search for the diamond target anymore (see Theeuwes, 1992, Exp. 3). Because the order of selectivity was completely dependent on the relative salience of the target and the distractor singletons, it was argued that initial selection was fully driven by physical saliency of the stimuli.

In all these previous studies, salience is defined as a physical property, expressing how different a particular location is from its surrounding in color, orientation, motion, depth, etc. (Itti & Koch, 2001). However, several recent studies have shown that a stimulus that is associated with reward may change its physical salience in such a way that it becomes more pertinent than that very same stimulus when it is not associated with reward. For example, in a recent study Hickey, Chelazzi, and Theeuwes (2010a) had observers perform a visual search task (the above described additional singleton task of Theeuwes (1991,1992)) in which they searched for a uniquely shaped target presented among a number of homogenous distractors. In Hickey et al. observers received, randomly assigned, either a high or low-monetary reward following each trial. The results showed that when observers received a high reward after responding to a target shape having a particular color, they responded quickly on the next trial when

* Corresponding author. Address: Dept. of Cognitive Psychology, Vrije Universiteit, Van der Boechorststraat 1, 1081 BT Amsterdam, The Netherlands. Fax: +31 20 444 8832.

E-mail address: J.Theeuwes@psy.vu.nl (J. Theeuwes).

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the target had same color as on the previous one. Crucially, when on the next trial all colors swapped, and the distractor singleton had the same color as was rewarded on the previous trial, strong attentional capture was observed. No such effects were observed following low monetary reward. Hickey, Chelazzi, and Theeuwes (2010a) argued that reward leads to an automatic bias of attention.

Subsequent ERP analyses revealed that following a high-monetary reward, there was an increase in the amplitude of the lateral P1 component approximately 100 ms poststimulus. This increase in P1 reflects an amplification of early visual processing stages in extrastriate visual cortex, often associated with an increased saliency (Mangun, 1995). On the basis of these findings, Hickey, Chelazzi, and Theeuwes (2010a) concluded that reward changes the salience of a stimulus such that a stimulus that is associated with high reward appears to be more pertinent and therefore receives attentional priority above and beyond its physical salience. Crucially, Hickey et al. showed that these effects of reward on selection are not driven by strategic, top-down control. Hickey et al. claimed that stimuli that are associated with high monetary reward are represented more robustly in early visual areas of the brain than those very same stimuli when associated with low monetary reward (see also Serences, 2008; Shuler & Bear, 2006).

It is important to realize that the claim that reward changes the visual representation of stimulus features associated with that reward is quite different from the idea that following a reward, observers strategically seek out the stimulus that is associated with high reward and ignore the stimulus associated with low reward. Even though such strategic effects do play a role (see e.g., Ikeda & Hikosaka, 2003), theoretically they may not be that interesting since they represent nothing else than a strengthening of the attentional set to select stimuli associated with larger rewards over those associated with lower rewards (Maunsell, 2004). Crucially, Hickey, Chelazzi, and Theeuwes (2010a) showed that reward change the stimulus representation directly, independent and beyond strategic control.

There have been also other studies examining the impact of reward on the allocation of spatial attention. Della Libera and Chelazzi (2009) introduced a training phase in which observers had to learn to select and ignore particular stimuli which, after a correct response, were followed by high and low monetary rewards. During the test phase, observers became more efficient in selecting targets that were associated with high-monetary reward and at the same time had trouble ignoring distractors that were during training associated with high reward. Moreover, they also showed that this effect remained present several days later. Della Libera and Chelazzi concluded that attentional selection is strongly biased by the more or less rewarding consequences of the past encounters with these stimuli.

In yet another recent study, a similar effects of reward on spatial attention were reported. Anderson, Laurent, and Yantis (2011a) also used Theeuwes' additional singleton task and showed that learned value magnifies attentional capture. During a training phase, observers had to search for either a red or green target among differently colored nontargets. Following a correct response observers received a monetary reward; one of the two colors was associated with high and the other with a low reward. In the test phase, observers performed the additional singleton task, searching for a unique shape among all white elements. On half of the trials, one of the nontarget elements was colored either red or green. No reward was provided during the test phase. The results showed that the colored distractor associated with the high monetary reward caused significantly more distraction as evidenced by an increased time to find the target than a color singleton that was associated with the low monetary reward. Anderson, Laurent, and Yantis (2011a) concluded that a stimulus that is associated with high reward through reward learning magnifies distraction even after that stimulus no longer predicts reward. It is concluded that stimuli with increased learned value are prioritized even when they are not relevant for the current task.

In a similar study, Anderson, Laurent, and Yantis (2011b) showed that without training, a non-salient stimulus did not affect attentional priority, while following reward training, the presence of a non-salient distractor that was associated with reward, increased the time to find the target. It was concluded that non-salient stimuli imbued with value via associative learning will cause attentional capture even when the reward association is no longer in place.

Up till now these studies have looked at the effect of reward on the allocation of spatial attention. The notion is that the presence of a stimulus that is associated with a high monetary reward disrupts goal directed behavior. It is assumed that a high reward renders the distracting stimulus more salient causing more attentional capture than that very same stimulus when associated with low reward. However, all effects reported in these studies are indirect in the sense that these studies only show that it takes more time to find the target when a previously high rewarded distractor is present relative to a low rewarded distractor. The implicit assumption is that the high reward distractor captures attention more often than a low reward distractor (e.g., Anderson, Laurent, & Yantis, 2011a, 2011b). However this may not necessarily be the case. It is quite feasible that there are neither differences in the amount of attentional capture between high versus low rewarded distractors (as in Anderson, Laurent, and Yantis (2011a)), nor is there attentional capture by non-salient stimuli imbued with value via associative learning (as in Anderson, Laurent, and Yantis (2011b)). Instead it could be that high rewarded distractors simply hold attention longer than neutral or a low rewarded distractors. If that is the case, then the results of Anderson, Laurent, and Yantis (2011a, 2011b) that showed an impairment in search due to the presence of reward associated distractors may not be surprising; yet these results may have nothing to do with differences in attentional capture.

It is crucial to realize that attentional capture and the holding of attention are completely different processes (Born, Kerzel, & Theeuwes, 2011). Attentional capture is bottom-up in nature and is about selection priority while the disengagement of attention from a location is primarily driven by top-down processing and is concerned with post-selection processes. Initial capture is determined by stimulus salience: the distractor that is completely irrelevant for the task summons attention against the intentions of the observer (Theeuwes, 2010a, 2010b). However, holding attention after it is captured by the salient singleton is related to the top-down processing: if the distractor that captured attention looks like the target it may hold attention longer than when the distractor does not look like the target (e.g., Belopolsky, Schreij, & Theeuwes, 2010; Theeuwes, Atchley, & Kramer, 2000; Theeuwes, de Vries, & Godijn, 2003). The reason for holding attention longer is quite simple: when the distractor resembles the target, it takes more time to decide whether it is a target or a distractor. Obviously when attention is engaged longer at the distractor location, the time to find the target will increase as well. Yet, such an effect has nothing to do with salience-driven exogenous capture but has to do with processes following exogenous capture.

It is in fact quite feasible that the result of reward on attentional capture as for example reported by Anderson et al. (2011a, 2011b) is the result of holding attention instead of the assumed capture of attention. Once attention is capture by the distractor and it may be harder to disengage attention when it is associated with a high reward than with a low reward. It simply may be harder to "let go" of the high rewarded stimulus as it previously predicted high monetary reward. The data of Anderson et al. (2011a, 2011b) cannot answer this question because the only effect that is seem is a longer

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reaction when a distractor associated with a high versus low reward.

The present study was designed to seek direct evidence for salience-based attentional capture by learned value. Instead of an attentional task we used an oculomotor task and examined whether a stimulus that is associated with a high monetary reward has the ability to capture the eyes more than that very same stimulus when associated with a low-monetary reward. Similar to Anderson, Laurent, and Yantis (2011a) we trained observers to associate one stimulus (e.g., a vertical line segment) with a high monetary reward and another stimulus (e.g., a horizontal line segment) with a low monetary reward. During the test phase, these stimuli were distractors while observers searched for a color singleton. We examined whether the eyes would be captured by the distractor line segments and whether this effect was modulated by the learned associated monetary reward.

The measurement of eye movements and fixations enables us to directly monitor the effect of reward on spatial attention. It is well-known that there is a tight coupling between saccadic eye movements and shifts of spatial attention. Many studies have indicated that before an eye movement is executed to a new location, spatial attention is first covertly shifted to the new location (Deubel & Schneider, 1996; Godijn & Theeuwes, 2004; Belopolsky & Theeuwes, 2009, in press). That is, although it is possible to shift attention covertly without a shift in gaze, it is not possible to shift the eyes without first shifting attention. This makes involuntary saccadic eye movements an ideal index of spatially-localized shifts of attention.

The present study uses a variant of oculomotor capture paradigm of Theeuwes et al. (1998, 1999). These studies using this paradigm have clearly demonstrated that even when observers have a strong top-down goal to look for a specific target, an irrelevant salient onset distractor may capture the eyes (Theeuwes et al., 1998, 1999; Godijn & Theeuwes, 2002). In these previous studies, observers could not help it that their eyes moved against the instructions, to a location that was completely irrelevant. The present study examines whether learned reward value has a similar effect and tests whether stimuli that are associated with high reward have a stronger effect on our oculomotor system than those very same stimuli when associated with low reward.

2. Method

2.1. Participants

Sixteen naïve participants (12 females, age range 19–27 years) with normal or corrected to normal vision participated in the experiment.

2.2. Apparatus

The stimuli were presented on a 21-in. monitor running at 75 Hz with a 1024 × 768 pixels resolution. Eye movements were recorded with the head-mounted EyeLink-II system (SR Research, Mississauga, Ontario, Canada) with 500 Hz temporal and 0.2° spatial resolution. An automatic algorithm detected saccades using minimum velocity and acceleration criteria of 35°/s and 9500°/s^2 respectively.

2.3. Stimuli, design and procedure

All stimuli were presented on a circumference of an imaginary circle with a radius of 9° of visual angle. Each observer was seated 75 cm from a computer screen, with head positioned on a chinrest. The stimuli were presented on a black background. Every trial began with the participants fixating the dot (0.5° in diameter) at the center of the screen and pressing a spacebar to start. All participants first completed a training phase followed by a test phase.

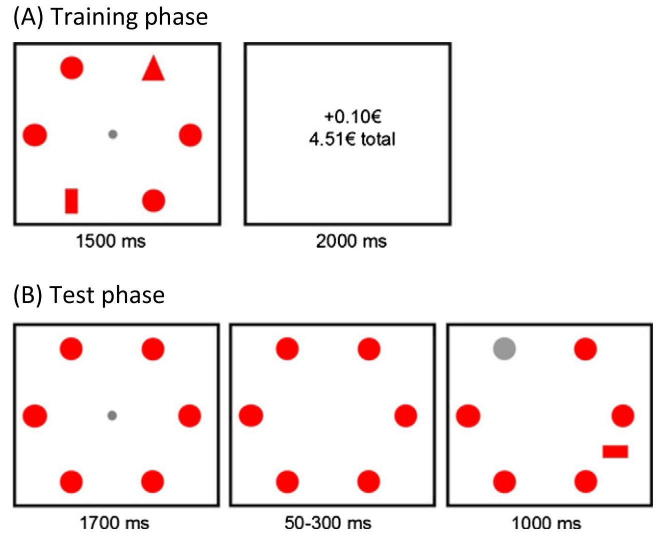

Fig. 1. Illustration of events occurring on a typical trial in the training phase (A) and in the test phase (B).

In the training phase (Fig. 1A) after a random delay of 800–1300 ms as search display was presented. It consisted of six red (9.7 cd/m^2) objects presented at 1, 3, 5, 7, 9 and 11 clock positions on the imaginary circle. Participants were instructed to search either for a horizontal or a vertical bar (width 0.9°, height 2.7°) that was presented among four circles (diameter 2.7°) and one triangle (width and height 2.7°). Either horizontal or vertical bar was present in the display at one time and participants were instructed to make a single saccade to its location. The search display stayed on the screen for 1500 ms. Participants were instructed to be as accurate and as fast as possible, and were told that their correct performance was rewarded. After each trial they received a feedback about the reward (10 cents or 1 cent) that they obtained on that trial as well as their accumulated reward. However, in reality the amount of reward was not related to their performance. Instead, when participants made a correct saccade to the target they received a reward contingent upon the orientation of the target. Half of the participants received on average a higher reward when the target was vertical and another half of the participants received on average a higher reward when the target was horizontal. The reward schedule was probabilistic, such that trials with a high reward stimulus were followed by high reward (10 cents) on 80% of the trials and by low reward (1 cent) on 20% of the trials. Vice versa, trials with a low reward stimulus were followed by low reward (1 cent) on 80% of the trials and by high reward (10 cent) on 20% of the trials. All experimental trials were divided in 6 blocks of 40 trials. After each block participants received feedback about their average saccade latency and accuracy, as well as the accumulated reward. The training phase started with a practice block of 40 trials that was identical to the rest of the experiment except that no reward was given and no feedback was provided.

Immediately after completing the training phase, the test phase began (Fig. 1B). In this phase participants did not receive any monetary reward. The trial began with the participants pressing a spacebar to start. After 1700 ms a display of six red circles appeared presented at 1, 3, 5,7, 9 and 11 clock positions on the imaginary circle and stayed on for 1000 ms. To speed up the eye movements the fixation point was turned off and after a randomly chosen time (between 50 and 300 ms) before the search display was presented. The search display consisted of one of the circles changing its color to equiluminant gray (9.9 cd/m^2). The target was equally likely to be presented at locations 1, 5, 7 and 11. Participants were instructed to move their eyes to the target as quickly and as accurately as possible. On two-thirds of the trials at the same time as the target was presented an irrelevant object was presented at a previously unoccupied location. It was equally likely to be either a vertical or a horizontal red bar and could appear at the locations 2, 4, 8 and 10, with a constraint that it could never appear adjacent to the target. The new object was equally likely to be presented with an angular distance of +90°, −90° and 150° from the target. On another one-third of the trials there was no new object. The search display was presented for 1000 ms. The test phase started with a practice block of 36 trials in which the new object was absent. In total there were six blocks of 36 trials. After completion of the test phase participants had to answer the following question: "In the training phase did you notice any association between the target orientation and the amount of reward?" In case when participants responded "Yes" a second question was asked: "Which orientation was associated with a higher reward?" After completion of the experiment participants were paid the amount of money that they earned. The average pay was 20.8 euro (range between 16.4 and 22.1).

Trials with saccades faster than 80 ms and slower than 600 ms and saccades that did not start within 1° away from fixation point were discarded from further analyses. This resulted in an average loss of 3% of trials. Saccades that landed within 15° of arc from the center of the saccade target were classified as correct. Saccades that landed within 15° of arc from the center of the onset distractor in the test phase were classified as going to the onset. When asked at the end of the test phase, four out of sixteen participants reported noticing the relationship between the orientation of the target and the given reward in the training phase. This did not seem to have any influence on the results.

2.3.1. Training phase

To examine whether participants have learned the reward schedule the performance for the first three and the last three blocks of the training phase was compared. A within-subjects ANOVA on saccadic latencies showed no main effects ($Fs < 1$). There was a marginal Block × Reward interaction ($F(1,15) = 3.92$, $p = .06$). In the first three blocks there was no significant difference in saccade latencies to the high (252 ms) and low reward targets (248 ms; $t(15) = 1.42$, $p = .18$). However, in the last three blocks participants were marginally faster in making a saccade to the high reward target (248 ms) comparing to the low reward target (250 ms; $t(15) = 2.08$, $p = .06$; see Fig. 2). Participants were very accurate in making a saccade to the target (96%). There was no difference in accuracy between the high and low reward targets for either first three or the last three blocks ($ts < 1$). The results from the training phase suggest that participants had successfully learned the reward schedule and after completing the training phase were somewhat faster in selecting the orientation that was on average associated with a higher reward.

2.3.2. Test phase

The appearance of the onset had a profound effect on the eye movement behavior in all but three participants, who basically showed no oculomotor capture. On average the eyes first went in the direction of the onset on 12.7% of the trials (Fig. 3). A within-subject ANOVA on the amount of capture showed a main effect of reward ($t(15) = 2.5$, $p < .05$), e.g. the eyes were captured more often by the onset distractor previously associated with high reward (14.4%) than by the onset distractor previously associated with low reward (10.9%). The duration of fixations on the onset distractor following oculomotor capture was not different between distractors previously associated with high or low reward (75 versus 71 ms, respectively; $t(15) = 1.67$, $p = .12$).

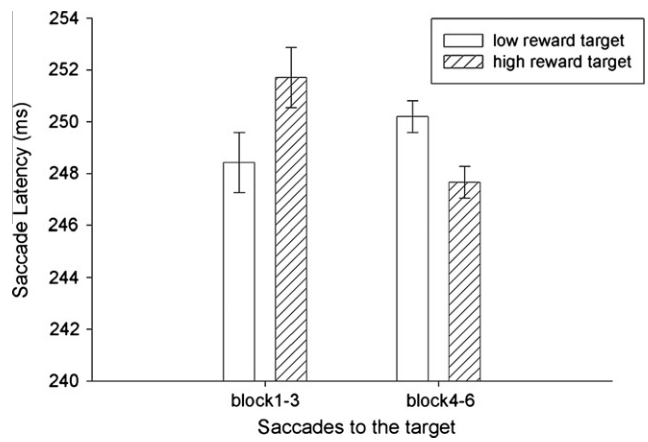

Fig. 2. Results of the training phase. In the first half of the experiment (block 1–3), there was no difference in saccadic latencies for saccades towards stimuli associated with either a high or low monetary reward. In the second half (block 4–6) observers were faster in making a saccade toward a stimulus associated with high reward than a stimulus associated with a low reward. Error bars show ±1 SEM normalized for within-subject design (Loftus & Masson, 1994).

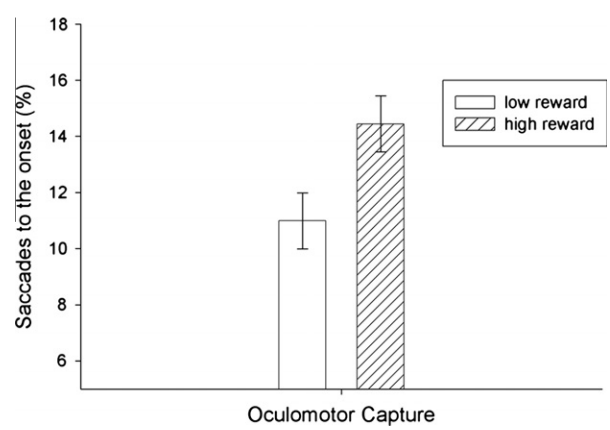

Fig. 3. Results of the test phase. The onset distractor that was associated with a high monetary reward during the training session capture the eyes more often than the onset distractor that was associated with a low monetary reward. Error bars show ±1 SEM normalized for within-subject design (Loftus & Masson, 1994).

The first saccades directed to the target were significantly slower when the onset distractor was present (226 ms) than when it was absent (205 ms; $t(15) = 6.51$; $p < .001$). The saccade latency was not affected by whether a high reward or a low reward distractor was present (227 ms versus 225 ms, respectively; $t < 1$).

To examine whether the oculomotor capture by high and low reward distractor changed over time the data from the test phase was split in half (Fig. 4). There was a main effect of half $F(1,15) = 5.47$, $p < .05$), suggesting that the amount of oculomotor capture decreased in the second half of the experiment. The interaction Half × Reward $F(1,15) < 1$) was not significant.

3. General discussion

The present study shows that a stimulus that is associated with a high monetary reward has the ability to capture the eyes in a stronger fashion than that very same stimulus that is associated with a low reward. Our study is the first to show that actual learned value of a stimulus has a differential effect on the saccadic

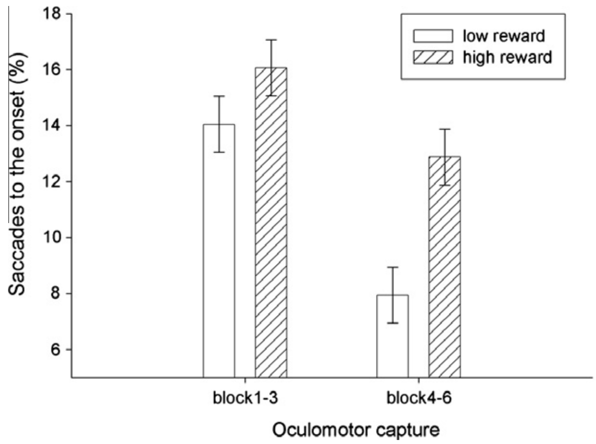

Fig. 4. Results of the test phase. Even though the overall capture became smaller over blocks of trials (first versus second half of the experiment), the amount of oculomotor capture between a distractor associated with either a high or low monetary reward remained basically the same across the experiment. Error bars show ±1 SEM normalized for within-subject design (Loftus & Masson, 1994).

eye movement system. Crucially, even when the stimulus no longer predicts reward, the learned value increases exogenous oculomotor capture above and beyond the oculomotor capture that is driven by salience alone.

While previous studies have demonstrated that the learned value of high and low monetary reward affects the allocation of attention (Anderson, Laurent, & Yantis, 2011a, 2011b; Della Libera & Chelazzi, 2006, 2009; Hickey, Chelazzi, & Theeuwes, 2010a), the present study demonstrates that not only spatial attention is affected but also the saccadic eye movement system. Indeed, the eyes were more frequently captured by a distractor that was – during training – associated with a high monetary reward than by the very same stimulus which was associated during training with a low monetary reward (see Fig. 3).

Overall, the current findings are consistent with those of Anderson, Laurent, and Yantis (2011a, 2011b). They also used an additional singleton task but they only measured manual reaction time. Crucially they showed that the time to find the target was significantly longer when a colored distractor associated with the high monetary was present relative to the condition in which a distractor associated with the low monetary was present. Even though they concluded that learned value magnifies attentional capture, they had no direct evidence for this claim as they only showed that it took longer to find the target when a high rewarded distractor was present relative to a distractor associated with a low reward. Anderson, Laurent, and Yantis (2011a) realized this caveat and pointed out it is feasible that learned value of a stimulus may not have changed the amount of capture but instead may have increased time it takes to disengage attention from distractor stimulus after attention has been captured (so called attentional dwell time; see also Belopolsky, Schreij, & Theeuwes, 2010; Theeuwes, 2010a, 2010b). It is certainly possible that the time to disengage attention from a high rewarded stimulus is longer than that from a stimulus associated with a low reward. For example, Born, Kerzel, and Theeuwes (2011) showed that oculomotor capture and disengagement are dissociable processes which are affected by different stimulus properties. For example, a distractor that looks like the target (e.g., distractor with a similar color as the target) does not cause more oculomotor capture but does significantly increase the time to disengage attention (Born, Kerzel, & Theeuwes, 2011).

The current findings show no differences of learned value on fixation durations following oculomotor capture suggesting that the time to disengage the eyes does not play a determining role in the effects of reward. This suggests that the post-capture dwell time account is less likely. The findings corroborates the notion that reward changes the salience of the stimuli such that they receive attentional priority independent of strategic control (Anderson et al., 2011a, 2011b; Della Libera & Chelazzi, 2006, 2009; Hickey, Chelazzi, & Theeuwes, 2010a, 2010b, 2011). Specifically, it was concluded that reward changes the salience of a stimulus such that a stimulus that is associated with high reward receives attentional priority independent of strategic control. Hickey, Chelazzi, and Theeuwes (2010a, 2011) argued that stimuli that are associated with high monetary reward are represented more robustly in early visual areas of the brain than those very same stimuli when associated with low monetary reward.

It is important to note that when an onset was present, saccades that went directly to the target were about 20 ms slower than when such an onset was not present, a results that nicely replicates our previous findings using the oculomotor capture paradigm (e.g., Godijn & Theeuwes, 2002). Notably, however, there were no differences in saccade latencies between conditions in which a high versus a low rewarded distractor was present. This finding is intriguing, as it suggests that the actual reward value has no competing effect on the programming of the saccade to the target (as is assumed for example in the competitive integration of model of Godijn & Theeuwes, 2002). The presence of an onset has a competing effect on the speed of executing the saccade to the target of about 20 ms; yet, the actual reward value (high versus low reward) has no competing effect. It suggests and this is purely speculative that reward value lowers the threshold to trigger a saccade. Because the threshold is lower, the number of saccades to the high value distractor is higher than for the low valued distractor. Yet this occurs without affecting the sub-baseline inhibition of more distant locations and therefore the saccade latency to the target is not affected by the actual reward value (see Figure 1 of Godijn and Theeuwes (2002)).

Our results show a robust effect of the learned value obtained during training. While in Anderson, Laurent, and Yantis (2011a) the difference in attentional capture by high versus low rewarding stimuli became smaller over time, our data indicate that capture for high versus low rewarded stimuli remained equally strong over all the blocks of the test phase. Even though the overall amount of capture became smaller over blocks, the difference in the amount of capture between high versus low rewarding distractors did not change.

It should be noted that the current findings are inconsistent those of a recent study by Anderson and Yantis (in press). That study, which is similar to the current one, also examined whether learned value of a stimulus had a differential effect on saccadic eye movements. As in Anderson, Laurent, and Yantis (2011b), during training observers learned to associate one stimulus with a high reward and another stimulus with a low reward. Even though the results indicated an effect of the presence of the distractor (relative to a no distractor condition), there was no difference in the degree of impairment caused by the low- and high value distractors. Crucially, unlike the current study, the Anderson and Yantis (in press) study showed no effect of a learned value (i.e., whether a distractor was associated with a high or a low reward) on the amount of oculomotor capture. It is possible that Anderson and Yantis (in press) did not find such an effect because they used displays in which multiple colors were present. Such "serial search like" displays may preclude the occurrence of oculomotor capture (see Godijn & Theeuwes, 2002; Theeuwes et al., 2003).

The present study demonstrates that stimuli previously associated with high reward not only capture attention, but they also capture our eyes against our intentions. This finding is important because it is feasible that a salient singleton captures attention without triggering an actual saccade to its location. For example, Theeuwes, de Vries, and Godijn (2003) showed that static singletons may capture attention without a subsequent eye movement. It was speculated if after initial capture, attention is disengaged very quickly (before the threshold for a saccade is reached), one may get attentional but no oculomotor capture. Clearly this is not the case here, the distractor summoned a saccade and more so when this distractor was associated with high reward.

These findings are consistent with Hickey, Chelazzi, and Theeuwes (2010a) who showed that attention was automatically biased towards a stimulus that is associated with a high reward while this effect was not observed for stimuli associated with a low reward. Crucially, Hickey, Chelazzi, and Theeuwes (2010a) showed that this automatic bias toward stimuli associated with high monetary reward could not be altered an a top-down, strategic manner, similar to the automatic capture of the eyes by stimuli associated with high reward that we observed in current study.

The present study shows that a stimulus that is associated with a high monetary reward disrupts goal directed behavior. When a stimulus is associated with high reward it has the ability to capture the eyes is stronger than that very same stimulus when associated with low reward. Consistent with previous studies, we provide direct evidence that reward may alter the salience of a stimulus in such a way that the stimulus associated with high reward can capture the eyes and disrupt on-going goal directed behavior. Similar behavior is seen in people that try to beat their drug addiction: even though they do not want to look at objects associated with the drug, they may find themselves staring at a pack of cigarettes, a bottle of alcohol or greasy food (Field & Cox, 2008).

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