

# Reward Determines the Context-Sensitivity of Cognitive Control

Senne Braem  
Ghent University

Clayton Hickey  
University of Trento and  
VU University Amsterdam

Wout Duthoo and Wim Notebaert  
Ghent University

Reward is thought to enhance cognitive control processes in various ways, but the impact of reward on the context-sensitivity of cognitive control remains unclear. Evidence from perception and attention studies suggests that a good outcome, in contrast to a suboptimal outcome, acts to increase saliency and attentional capture for attended visual features that led to this outcome. As a consequence, such features gain a competitive advantage in future perception. In the present article, we investigate the possibility that this interplay between reward and contextual visual features can impact the scope of higher cognitive control processes, specifically conflict monitoring. To this end, we ran 2 experiments. First, by combining a visual search paradigm with a letter flanker task, we demonstrate how the congruency sequence effect can be observed when salient task irrelevant features repeat, but disappears when those features alternate. These findings are in line with earlier observations on the context-sensitivity of cognitive control. In a second experiment, we added a reward manipulation, demonstrating that this context-sensitivity is promoted following high reward but disappears following low reward. The results suggest a role for reward in modulating the context-sensitivity and scope of cognitive control.

*Keywords:* reward, cognitive control, reinforcement learning, associative learning

To achieve our goals, we must monitor our environment and adapt to ever-changing contexts. Feedback regarding action outcomes is well known to play a role in guiding this type of cognitive control. In spite of this, cognitive control researchers have only recently started to investigate the manner in which explicit feedback impacts cognitive control processes (e.g., Braem, Duthoo, & Notebaert, 2013a; Braem, Verguts, Roggeman, & Notebaert, 2012; Jiang & Xu, in press; Stürmer, Nigbur, Schacht, & Sommer, 2011). Recent empirical evidence has demonstrated how trial-to-trial cognitive adaptations processes can be tied to specific stimulus (Spapé & Hommel, 2008) or response features (Braem, Verguts, & Notebaert, 2011), arguing for the context-sensitivity of cognitive control (Blais, Robidoux, Risko, & Besner, 2007; Davelaar & Stevens, 2009; Verguts & Notebaert, 2008, 2009). In the present study, we

investigated how reward feedback can play a role in determining the impact of contextual task features on cognitive control.

Generally, cognitive control is investigated through the use of conflicts tasks like the Eriksen flanker task (Eriksen & Eriksen, 1974), Stroop task (Stroop, 1935), or Simon task (Simon, 1969). In all these paradigms, irrelevant, conflicting stimulus information impedes the processing of relevant stimulus information. For example, in a standard flanker task, participants are required to respond as fast as possible to a centrally presented target (e.g., press left when 'S,' right when 'H'). Irrelevant flankers presented next to the central target impede task performance when they are incongruent, as when these letters are associated with an alternative response (e.g., 'HSHH'), but facilitate task performance when congruent, as when they are the same letters as the central target (e.g., 'SSSS'). Resulting differences in reaction time (RT) and accuracy are referred to as the congruency effect.

The congruency effect observed in the flanker task is typically found to be smaller after incongruent trials than after congruent trials (as first observed by Gratton, Coles, & Donchin, 1992). This congruency sequence effect has been replicated in different congruency tasks (Kerns et al., 2004; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002) and offers an index of how people increase task focus in reaction to cognitive conflict. Furthermore, the congruency sequence effect appears to be context-specific, restricted to circumstances where perceptual context repeats between experimental trials. Spapé and Hommel (2008), for example, demonstrated how the congruency sequence effect could only be observed when the voice in which the stimulus was presented repeated between trials. In a similar vein, Braem, Verguts, and Notebaert (2011) found that the congruency sequence effect only

---

This article was published Online First August 4, 2014.

Senne Braem, Departments of Experimental Psychology and of Experimental Clinical and Health Psychology, Ghent University, Belgium; Clayton Hickey, Center for Mind/Brain Sciences, University of Trento, Italy; Department of Cognitive Psychology, VU, University Amsterdam, The Netherlands; Wout Duthoo and Wim Notebaert, Department of Experimental Psychology, Ghent University, Belgium.

Senne Braem and Wim Notebaert (Grant G.0098.09N), as well as Wout Duthoo (Grant 3F009109), were supported by the Research Foundation Flanders (FWO). Clayton Hickey was supported by the Netherlands Organization for Scientific Research (NWO) VENI Grant 016-125-283.

Correspondence concerning this article should be addressed to Senne Braem, Experimentele Psychologie, Henri Dunantlaan 2, B-9000 Ghent, Belgium. E-mail: [Senne.Braem@ugent.be](mailto:Senne.Braem@ugent.be)

occurs within response effectors (feet or hand), but not across. This is in line with recent associative models of cognitive control (Blais, Robidoux, Risko, & Besner, 2007; Davelaar & Stevens, 2009; Verguts & Notebaert, 2008, 2009) that stress the importance of modulating task associations after conflict. For example, Verguts and Notebaert (2008, 2009), in their adaptation-by-binding account, proposed that cognitive conflict triggers an arousal signal that is sent throughout the brain, strengthening all active representations. Task-relevant associations will be more strongly modified, resulting in a smaller congruency effect on the next trial. By explaining the congruency sequence effect in terms of strengthening specific stimulus–response associations (in contrast to, e.g., enhancing overall task focus; Botvinick, Braver, Barch, Carter, & Cohen, 2001), this model provides a context-sensitive implementation of cognitive control. Specifically, because the model postulates that conflict adaptation occurs by strengthening all active features and representations, the adaptation process will naturally be sensitive to what is active or salient at the time. Given that reward is known to modulate the saliency or relative activation of stimuli (see next paragraph), we expect reward signals to play a major role in determining the context-specificity of cognitive control. First, we will give a brief introduction into the reward literature, after which we will focus on a particular reward paradigm of interest that will allow us to investigate the influence of reward on contextual modulations of cognitive control.

For over a century, psychologists have been discussing and investigating the effects of reward on behavior (Schultz, 2002; Skinner, 1953; Thorndike, 1911). Reward signals are widely thought to reinforce stimulus–response associations (i.e., the law of effect; Thorndike, 1911). Neurophysiological data suggest that this effect relies on dopaminergic signaling in the midbrain (Kelley, 2004; Robbins & Everitt, 1996; Schultz, 2002, 2004). For example, reward has been found to stimulate the potentiation of connections between striatum and cortex in rats, with the strength of this physiological effect predicting the animal's subsequent ability to learn a new task (Reynolds, Hyland, & Wickens, 2001). Similar behavioral effects have been observed in humans, with reward—in the form of positive valence inducing pictures—increasing both short- (Colzato, van Wouwe, & Hommel, 2007) and long-term (Waszak & Pholulandeth, 2009) stimulus–response associations.

In recent years, reward has also become a focus for researchers investigating selective attention (Anderson, Laurent, & Yantis, 2011a, 2011b, 2012; Anderson & Yantis, 2013; Della Libera & Chelazzi, 2006, 2009; Hickey, Chelazzi, & Theeuwes, 2010a, 2010b, 2011; Hickey & van Zoest, 2012, 2013; Raymond & O'Brien, 2009; Rutherford, O'Brien, & Raymond, 2010). For example, Hickey, Chelazzi, and Theeuwes (2010a) demonstrated that selective attention is automatically biased toward stimuli with reward-associated visual features. These authors asked human participants to search for a uniquely shaped target presented among a number of homogenous distractors. Response was based on the orientation of a small line presented within the target shape. In some trials, all the shapes were of the same color, but more often one of the distractor shapes had a different color, rendering it a type of distractor known to draw attention during search (from here on referred to as the visual search distractor; e.g., Hickey, McDonald, & Theeuwes, 2006; Theeuwes, 1991). The stimuli colors varied from trial to trial and the colors could either swap,

with the color of the target shape becoming that of the visual search distractor and the color of the distractor that of the target, or they could remain the same. Participants randomly received either high- or low-magnitude monetary reward after each correct trial. Results showed that when high reward was received, attention was biased toward stimuli with the same color in the next trial. Even though color was task irrelevant, task performance thus improved when target color repeated, but suffered when target color alternated and the salient visual search distractor acquired the reinforced color. This is consistent with the notion that target features are prioritized in future perception because target features, and not distractor features, led to the correct response, and hence high reward (for a review, see Anderson, 2013). Indeed, in a follow-up study, Hickey, Chelazzi, and Theeuwes (2011) further demonstrated how this modulation by reward is specific to the enhancement of visual target features, rather than the suppression of distractor features. It is interesting that this pattern is diminished, or sometimes even reversed, following low reward (Hickey et al., 2010a, 2010b, 2011). It thus seems that reward can modulate the relative saliency of task-irrelevant contextual stimulus features (i.e., color).

The idea that reward can determine the saliency of task-irrelevant features is particularly interesting in the light of the results from Spapé and Hommel (2008) suggesting that irrelevant features can determine the scope of cognitive control: this study demonstrated that adaptations to conflict can be determined by task-irrelevant contextual features, opening the possibility that reward modulations of the saliency of such features could determine the impact of these features on cognitive control. To investigate this effect of reward on a context-sensitive conflict task, we designed an experimental paradigm that integrated the visual search task employed by Hickey, Chelazzi, & Theeuwes (2010a) with a flanker task. In each trial, participants looked for an object with a unique shape and responded based on the identity of the central letter in a letter sequence contained within that target shape.

This design allowed us to detect the influence of reward signals and contextual features on the congruency sequence effect. Experiment 1 was designed to determine whether context-sensitive conflict adaptation could be replicated in a visual search paradigm in the absence of a reward manipulation. We predict that color (context) repetitions, but not color (context) alternations, would set the stage for a congruency sequence effect. In Experiment 2, we included reward feedback at the end of each trial. We approached this second experiment with the notion that this context-sensitivity of the congruency sequence effect (i.e., adaptation by binding, Verguts & Notebaert, 2008, 2009) and reward modulation of contextual features (Hickey et al., 2010a, 2010b, 2011) would combine to produce an *increased* congruency sequence effect when target and visual search distractor colors repeated after high reward, but a *decreased* effect when these contextual features alternated after high reward (i.e., similar to our observation in Experiment 1). After low reward, on the other hand, we expected that this context-sensitive pattern would disappear, or even reverse (i.e., the congruency sequence effect would not be susceptible to context repetitions/alternations). In addition to this, we expected that individual variability in the effect of reward might be predicted by measures of personality, and specifically the behavioral inhibition system (BIS) and behavioral activation system (BAS)

scale of Carver and White (1994). Subscales of this measure have been found to predict the impact of reward in other visual search (Beaver et al., 2006; Hickey, Chelazzi, & Theeuwes, 2010b) and cognitive control tasks (Braem et al., 2012; van Steenbergen, Band, & Hommel, 2009).

## Experiment 1

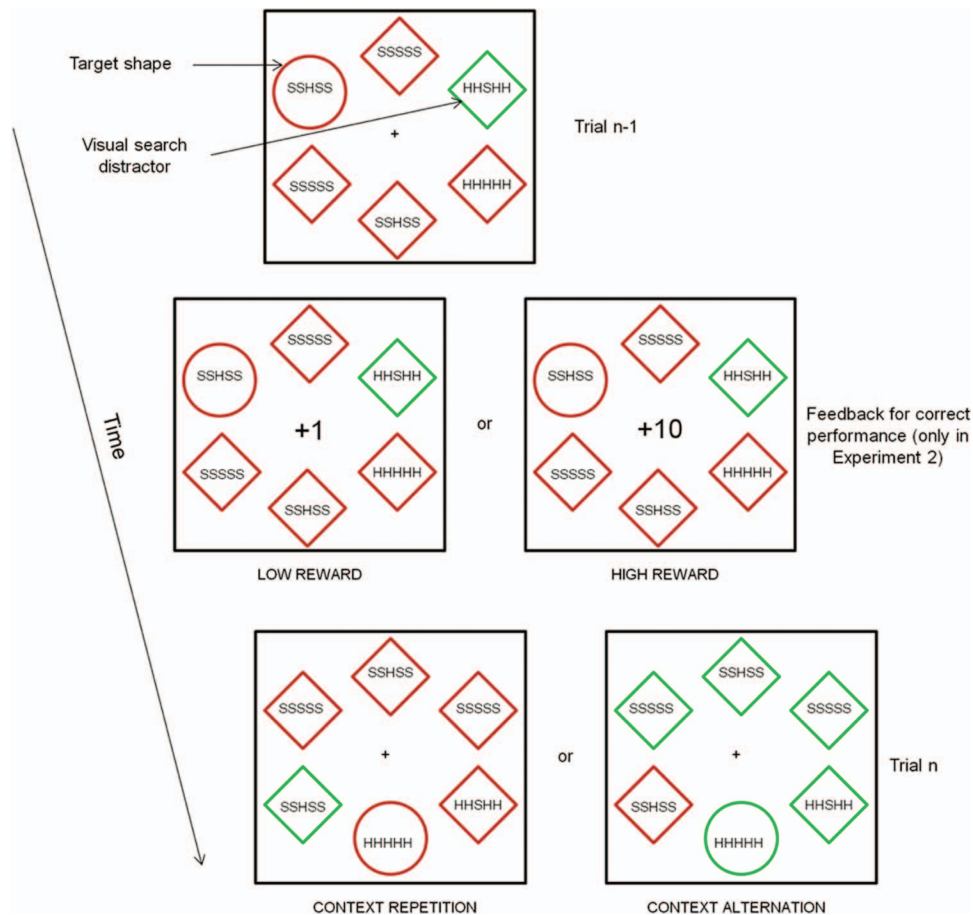
### Method

**Participants.** Fifteen students (range = 18–23 years, 10 women, all right-handed) took part in return for course credits.

**Stimuli.** Stimuli were presented on a cathode ray tube monitor located 60 cm away from the eyes using Tscope software (Steven, Lammertyn, Verbruggen, & Vandierendonk, 2006). The visual search arrays contained six object outlines (line thickness of  $0.3^\circ$  visual angle), each presented equidistant ( $9.1^\circ$ ) from a central fixation point and from each other. Objects could be diamonds ( $4.2^\circ \times 4.2^\circ$ ) or circles ( $3.4^\circ$  diameter), with each display containing only one uniquely shaped item. This search target (i.e.,

shape singleton) could be a diamond with all other stimuli circles or vice versa. In 80% of trials, one of the homogeneously shaped nontarget items was of unique color (i.e., color singleton), either red with all other objects green or vice versa. Both the search target and each of the nontargets contained a sequence of five horizontally aligned characters (SSSSS, HHHHH, HSHHH, or SSHSS).

**Procedure.** The trial procedure is visualized in Figure 1. Participants responded based on the central character in the search target: half of the participants pressed the left response button when this letter was an ‘S’ and the right button when it was an ‘H.’ This response mapping was reversed for the other half of the participants. Nontarget characters could have the same identity, rendering the flanker target congruent (e.g., SSSSS), or could have the alternative identity, rendering the flanker target incongruent (e.g., HSHHH). Per block, search target shape (circle or diamond), search target color (green or red), flanker target congruency (congruent or incongruent), and search distractor presence (80% present and 20% absent), were randomized in a balanced manner.



*Figure 1.* General paradigm and trial procedure for Experiment 1 and 2. The target shape and uniquely colored visual search distractor are denoted (dark and light grey in the print version denotes red and green, respectively). Participants had to identify the unique (target) shape, while ignoring the visual search distractor, and respond to the central letter in the target shape (Flanker task). In Experiment 2, correct performance was rewarded with either 1 or 10 points. There was no reward schedule in Experiment 1. The color version of this figure appears in the online article only.

The onset of the visual search array was preceded by a fixation cross for a random duration of 400–1,400 ms. Responses were registered with a standard response box. Errors were indicated with the Dutch word *fout* (mistake) in black text for 500 ms. No feedback was provided for correct responses, but the fixation cross remained on the screen for an additional 500 ms in these trials. Participants completed 14 blocks of 40 trials for a total of 560 trials, which took approximately 40 min. A self-paced break was provided between blocks. All participants were given detailed instructions regarding the experimental task.

Note that, unlike most visual search experiments, we did not instruct participants to keep their eyes fixated on the fixation point. The fixation cross only served as a reference point for participants to return their eyes to during intertrial intervals (without explicit instruction to do so). During stimulus presentation, participants were free to fixate on target or distractor shapes. We did not restrict participants to keep their eyes fixated, because we assumed participants would not be able to detect the central target in our flanker task stimuli without moving their eyes to the target shape. Still, given that this represents an important procedural difference between our experiment and previous visual search experiments, we discuss the implications of this design feature in the general discussion.

## Results

Mean accuracy was high ( $M = 96\%$ ,  $SD = 0.04$ ). Sequential analyses are based on trials containing a visual search distractor

that were preceded by a trial containing a visual search distractor in the same block. RT analyses reflect only correct trials. Of these, 4.6% were RT outliers ( $\pm 2 SD$ ) and were discarded from further analysis. RT and accuracy results were statistically assessed in repeated-measures analyses of variance (rANOVA) with within-subject factors for flanker congruency (congruent vs. incongruent), previous flanker congruency (previous congruent vs. previous incongruent), color sequence (color repetition vs. color alternation), and shape sequence (shape repetition vs. shape alternation).

**Reaction times.** Overall, there was a significant flanker congruency effect,  $F(1, 14) = 27.114$ ,  $p < .001$ , which did not interact with previous flanker congruency,  $F(1, 14) = 1$ ,  $p > .1$ . Analysis further revealed a significant effect of shape sequence,  $F(1, 14) = 17.141$ ,  $p < .01$ , driven by faster RTs on shape repetitions relative to shape alternations. The three-way interaction between color sequence, flanker congruency and previous flanker congruency was significant,  $F(1, 14) = 5.433$ ,  $p < .05$ . As is depicted in Figure 2a, this indicates that the congruency sequence effect was only observed for color repetitions,  $F(1, 14) = 5.915$ ,  $p < .05$ , with no congruency sequence effect observed for color alternations,  $F(1, 14) < 1$ ,  $ns$ . In addition, we observed a significant interaction between congruency and shape sequence,  $F(1, 14) = 5.906$ ,  $p < .05$ , indicating a reduced congruency effect (60 ms) after shape alternations relative to shape repetitions (108 ms). No other interactions reached significance (all  $p > .1$ ).

**Error rates.** The error rates analysis only showed a marginally significant main effect of congruency,  $F(1, 15) = 3.182$ ,  $p =$

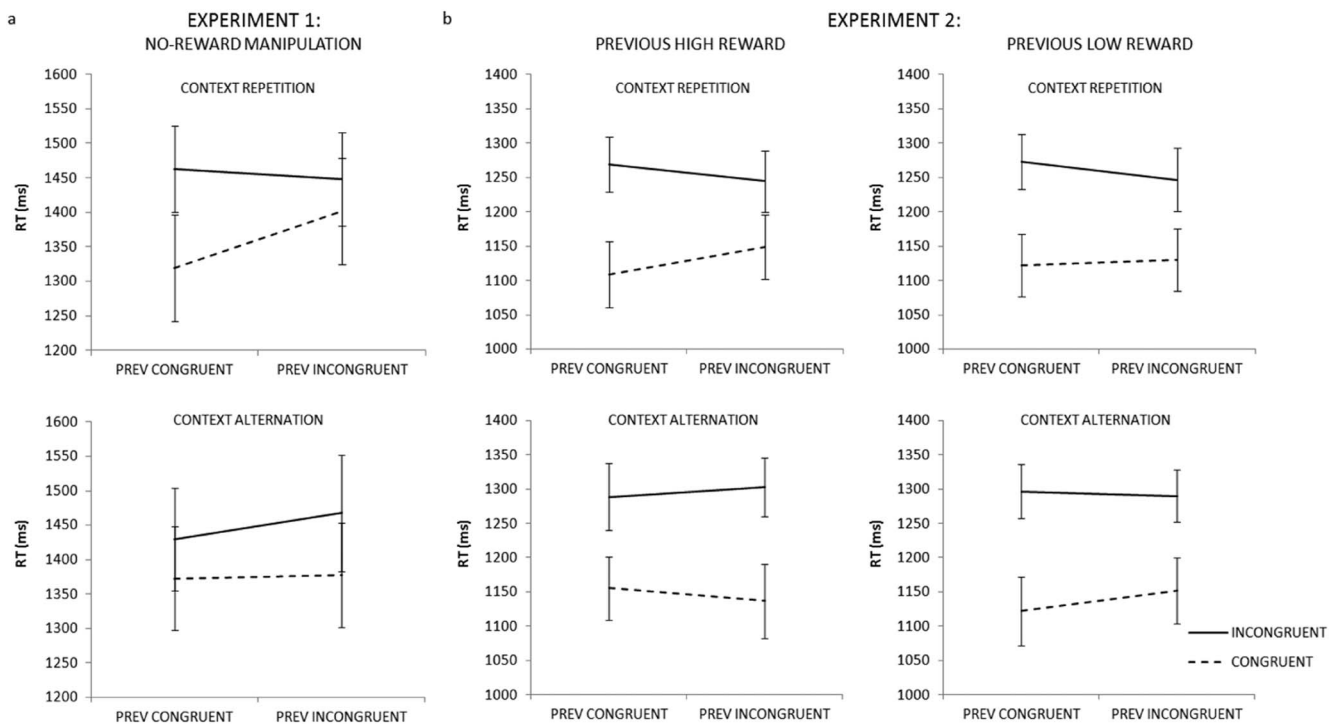


Figure 2. Reaction times for Experiment 1 (a) and Experiment 2 (b). Dotted lines indicate congruent trials and full lines indicate incongruent trials. The results demonstrate how conflict adaptation is normally observed for context repetitions only (Experiment 1). When implementing a reward schedule, this effect replicates after high reward, but not after low reward (Experiment 2). The error bars are  $\pm 1 SE$ .

.096, and an interaction between congruency and shape sequence,  $F(1, 15) = 4.591, p = .05$ , indicating a congruency effect on shape repetitions (2.8%), but not on shape alternations (−0.4%). No other interactions reached significance (all  $p > .1$ ).

**Manipulation check.** The analyses described previously are based on trials where the visual search distractor was present, and previous research showed that this color singleton will draw attention during search (e.g., Hickey, McDonald, & Theeuwes, 2006; Theeuwes, 1991). To verify this effect in the current dataset, we conducted an additional analysis contrasting distractor present and distractor absent conditions. A paired-samples  $t$  test revealed a significant difference in RT between distractor present and distractor absent trials,  $t(14) = 8.823, p < .001$ . Participants were 130 ms slower to respond in distractor present trials as opposed to distractor absent trials. Error rates indicated a similar trend but did not reach significance,  $t(14) = 1.620, p > .1$ .

## Discussion

This first experiment is in line with earlier observations suggesting that the congruency sequence effect is sensitive to changes in irrelevant stimulus characteristics or response modality (Braem et al., 2011; Fischer, Plessow, Kunde, & Kiesel, 2010; Spapé & Hommel, 2008). Here, we demonstrate that this effect can also be bound to contextual task-irrelevant features (surrounding color) in which task stimuli are presented, and suggest that context repetitions in visual search facilitate not only target detection and localization, but also the operation of subsequent mechanisms involved in conflict adaptation. We conducted a second experiment to determine if reward would modulate this effect of visual context on the congruency sequence effect. We employed much the same paradigm as in Experiment 1, but now added feedback at the end of each correct trial randomly signaling either a high or low reward.

In Experiment 1 flanker stimuli were randomly presented in nontarget shapes. If participants were to respond to the flanker target in the visual search distractor, and the flanker target happened to be the same as in the target shape, the response would have been erroneously coded as correct. As such, false positives might have contributed to the pattern of observed results. In order to control for this confound, the flanker task in Experiment 2 had four response options. This allowed us to ensure that neither flankers nor targets were the same in the visual search distractor shape and target shape, precluding false positive responses.

The four-choice task had additional benefits. In particular, it allowed us to investigate the impact of feature integration effects (Hommel, Proctor, & Vu, 2004). As noted by Hommel and colleagues (2004), the congruency sequence effect in two-choice conflict tasks can often be reinterpreted in terms of feature integration. Thus, whenever congruency conditions repeated in Experiment 1 (i.e., congruent trial following congruent trial, or incongruent trial following incongruent trial), the flanker and target identities always made complete repetitions or alternations (i.e., both alternated or both repeated). In contrast, congruency alternations (i.e., congruent trial following incongruent trial or vice versa) are characterized by either a flanker repetition or a target repetition, but never both. Given that complete repetitions/alternations are known to be processed faster than this sort of partial repetition, feature integration rather than conflict adaptation might be the

driving force behind the congruency sequence effect. The use of a response mapping with four options in Experiment 2 controlled for this confound and allowed us to investigate the relative contribution of feature integration to our results.

Experiment 1 had an additional limitation: after excluding errors and trials without distractors there were on average only 19 trials per cell of the experimental design. Given that the color singleton was found to robustly disrupt target search in Experiment 1, we increased this number by only including visual search distractor-present trials in Experiment 2. We also increased the length of the experiment, with participants completing 640 trials in total (80 more than in Experiment 1). The design of Experiment 2 thus garnered 39 potential trials per condition, reflecting an increase of roughly 90%.

## Experiment 2

### Method

**Participants.** Eighteen students took part for credit (range = 18–21 years, 15 women, 1 left-handed).

**Stimuli and procedure.** The trial procedure was similar to Experiment 1 with the following modifications (Figure 1): the shape singleton was always a circle and distractor-shapes were always diamonds, and correct responses to the search target were immediately followed by the replacement of the central fixation cross with reward feedback in black text, either '+10', denoting the receipt of 10 points, or '+1', denoting the receipt of 1 point. Per block, reward feedback (low or high reward), target color (green or red), and flanker task congruency (congruent or incongruent), were randomized in a balanced manner. The search array and flanker stimuli remained onscreen during the 1,000 ms presentation of feedback. Incorrect responses resulted in the removal of 10 points, denoted by '−10', and for every 10 participants that completed the experiment the top-scorer received a 25€ store coupon.

As noted previously, all trials had a uniquely colored distractor. As in Experiment 1, each of the six object outlines contained a sequence of five characters aligned horizontally and participants responded based on the central character. However, we employed a number, instead of letter, flanker task. All participants were required to press the 'D' key on the keyboard when the central target was number 1, the 'F' key when number 2, the 'J' key when number 3, and the 'K' key when number 4. This stimulus to response assignment (left to right, 1 to 4) was not counterbalanced across participants, because the order of this response mapping ensured the most efficient task performance (reducing the additional RT cost). Nontarget characters could have the same identity, rendering the target flanker congruent (e.g., 11111), or could have an alternative identity, rendering the target incongruent (e.g., 44144). To guarantee a balanced number of target-flanker combinations per congruency condition (see Mordkoff, 2012), we used a fixed selection of four incongruent trial types. Specifically, on incongruent trials target 1 was always flanked by 4 (i.e., 44144), 2 by 3, 3 by 1, and 4 by 2. The randomization and trial procedure was the same as in Experiment 1, except that participants completed 16 blocks (instead of 14). Each block consisted of 40 trials, and it took 45 min to complete the experiment.

**Questionnaires.** Participants in Experiment 2 completed a Dutch version (Franken, Muris, & Rassin, 2005) of the BIS/BAS scale (Carver & White, 1994) immediately after the experiment. In the BIS/BAS scale, participants rate their agreement with a series of 20 statements on a 4-point scale (e.g., “I go out of my way to get things I want.”).

## Results

Again, mean accuracy was high ( $M = 98\%$ ,  $SD = 0.01$ ). Mean RT was 204 ms faster than in Experiment 1. This could reflect a broad motivational impact of the reward feedback, but could also reflect the fact that the target shape in Experiment 2 was always a circle, and did not vary as it had in Experiment 1. This may have introduced a constant uncertainty about the exact target identity in Experiment 1 and such a reduction in top-down information is known to slow down visual search (e.g., Wolfe, Butcher, Lee, & Hyle, 2003).

Trials resulting in an error or preceded by an error were removed from analysis, as were the first trials of each block and trials resulting in outlier RT values ( $\pm 2 SD$ ; 3.9% of trials). RT and accuracy results were statistically assessed in a rANOVA with within-subject factors for flanker congruency (congruent vs. incongruent), previous flanker congruency (previous congruent vs. previous incongruent), color sequence (repetition or alternation), and previous reward (high vs. low magnitude). Analysis of RT revealed a significant congruency effect,  $F(1, 17) = 207.624$ ,  $p < .001$ , which interacted with previous congruency,  $F(1, 17) = 11.844$ ,  $p < .01$ , indicating an overall congruency sequence effect. Also, there was a significant effect of color sequence,  $F(1, 17) = 16.938$ ,  $p < .01$ , indicating shorter RTs on color repetitions relative to color alternations. Critically, the interaction between congruency, previous congruency, previous feedback and color sequence was significant,  $F(1, 17) = 9.746$ ,  $p < .01$ , demonstrating an impact of reward on the context-sensitivity of the congruency sequence effect. No other interactions reached significance (all  $p > .1$ ).

To disentangle this four-way interaction, we investigated the impact of color sequence on the congruency sequence effect following high and low reward separately. As depicted in Figure 2b, the congruency sequence effect interacted with color sequence following high reward,  $F(1, 17) = 6.188$ ,  $p < .05$ , demonstrating a significant congruency sequence effect when context repeated (65 ms),  $t(17) = 3.035$ ,  $p < .01$ , but not when the context alternated ( $-32$  ms),  $t(17) = -1.232$ ,  $p > .1$ . We thus replicate the context-sensitive congruency sequence effect observed in Experiment 1 after high reward, but not after low reward,  $F(1, 17) = 0.003$ ,  $p > .1$ . After low reward only a general congruency sequence effect could be detected (35 ms),  $F(1, 17) = 8.895$ ,  $p < .01$ . The analysis of error rates garnered no significant results (all  $ps > 0.1$ ).

The design of Experiment 2 allowed us to test for any possible influence of feature repetition and/or integration effects in the results (e.g., Hommel, Proctor, & Vu, 2004). To do so we further analyzed the data using multiple regression (Braem et al., 2012; Notebaert & Verguts, 2007). To account for between-subjects variance this regression was performed for each participant, with the cross-participant average of each coefficient subsequently tested against zero (Lorch & Myers, 1990). In addition to the

variables of interest identified in description of the rANOVA above this multiple regression analysis included an a further five binary factors: repetition of the target within the flanker sequence, repetition of the flankers within the flanker sequence, feature integration (coding for complete repetitions and alternations of target and flankers vs. partial repetitions, where either the flanker or target changed, but not both), negative priming (coding for whether the flanker became the target within the flanker sequence), and reverse negative priming (coding for whether the target became the flanker within the flanker sequence; see Notebaert & Verguts, 2007). The critical 4-way interaction reported above remained significant in this analysis,  $t(17) = 2.330$ ,  $p < .05$ . Main effects of feature integration, target repetition, and flanker repetition were additionally detected (all  $p < .01$ ), with negative priming showing a trend to significance,  $t(17) = 2.006$ ,  $p = .061$ .

## Correlation Analyses

Analysis of questionnaire results identified no reliable correlations.

## General Discussion

In this study we have demonstrated an impact of visual context on the congruency sequence effect (Experiment 1), and how the effect of context can be further modulated by reward (Experiment 2). In Experiment 1, we had participants complete a hybrid conflict/visual search task in which a response-relevant flanker stimulus was contained within the uniquely shaped visual search target. This target was often joined by a uniquely colored, task-irrelevant visual search distractor. Results showed a large and reliable congruency sequence effect when visual context (colors characterizing the target shape and visual search distractor) was the same as in the previous trial, but not when context alternated. In a second experiment, we provided reward feedback at the end of each trial and found that high reward modulated the impact of context on the congruency sequence effect. Specifically, in Experiment 2 we observed that the results observed in Experiment 1—a congruency sequence effect following context repetitions—appeared only when participants received high-reward in the preceding trial.

These findings demonstrate that reward can have a direct impact on the scope of cognitive control by enhancing contextual features that led to its receipt such as target color (relative to distractor color). This type of direct influence is consistent with theoretical models of conflict monitoring such as the adaptation-by-binding account of Verguts and Notebaert (2008, 2009). According to this model, adaptations to conflict occur after response execution (but can initiate earlier, see, e.g., Scherbaum, Dshemuchadse, Ruge, & Goschke, 2012), making them sensitive to feedback presentation and the environmental context present at that time. After high reward, the saliency of target contextual features is increased (or decreased after low reward). This sort of Hebbian learning can account for context- and reward-sensitive adaptations to conflict because it is thought to potentiate all active associations, including those that are activated by raw visual salience rather than task relevance. The impact of reward on conflict adaptation identified in our results confirms previous results of Braem et al. (2012) and

Sturmer et al. (2011). This general pattern has been interpreted as evidence that high reward may enhance the learning value of the conflict signal, creating a larger conflict adaptation effect. Low reward, in contrast, appears to devalue this learning signal and ultimately counteracts conflict adaptation. The current results further corroborate studies demonstrating the general contextual selectivity of conflict adaptation (Braem et al., 2011; Fischer, Plessow, Kunde, & Kiesel, 2010; Spapé & Hommel, 2008; Verguts & Notebaert, 2008, 2009).

The adaptation-by-binding model proposes that conflict adaptation depends on levels of activation, and therefore explains the specific effect of rewarded/unrewarded contexts without additional assumptions. Note, that in this regard, the model bears some similarities to the feature integration account (Hommel, Proctor, & Vu, 2004). Both accounts assume that active features are bound, but adaptation-by-binding suggests that this binding is sensitive to conflict, in the sense that stronger binding occurs when conflict is detected. The feature-integration account, on the other hand, argues that the congruency sequence effect emerges from the mere repetition or alternations of stimulus features. The current results seem inconsistent with this account, in that our multiple regression analysis demonstrates that mere repetition effects are not sufficient to account for the influence of reward on context-sensitive congruency sequence effects.

Although we believe that the results are most parsimoniously explained by the adaptation-by-binding model (Verguts & Notebaert, 2008, 2009), the experiment was not designed to differentiate between cognitive control models. The model of Botvinick et al. (2001) proposes that task focus is enhanced upon the detection of conflict. This model cannot explain the context-sensitivity of adaptations to conflict (our Experiment 1, see also Braem et al., 2011; Fischer, Plessow, Kunde, & Kiesel, 2010; Spapé & Hommel, 2008; Verguts & Notebaert, 2008, 2009). However, a relatively simple adjustment to the model can incorporate context or stimulus sensitivity (e.g., Blais et al., 2007). With such an addition, conflict monitoring theory would suggest that increases in conflict adaptation could result from the impact of reward on attention to context.

It is interesting that our Experiment 2 seems to demonstrate both a reduced (i.e., absent) contextual modulation of the congruency sequence effect following low reward and an enhanced modulation following high reward. This observation is concordant with earlier studies that investigated the effects of learning signals on behavior and observed an absence of their behavioral effect of interest following low or no learning signals (Braem et al., 2013a, 2012; Hickey et al., 2010a, 2010b, 2011; Jiang & Xu, in press; Muhle-Karbe & Krebs, 2012). Similarly, these studies demonstrated that the introduction of a motivationally significant learning signal creates a context where both the salient learning signal (i.e., high reward) and its counterpart (i.e., low reward or no reward) receive an informative value. The act of increasing motivation in high reward trials seems to have a corollary in low reward trials, decreasing motivation by a similar amount. This observation further relates to the more general idea that intrinsic motivation could play an underestimated role in cognitive tasks without performance feedback (Satterthwaite et al., 2012; Silvetti, Alexander, Verguts, & Brown, in press).

It is important to point out that the current results, like those reported by Braem et al. (2012) and Stürmer et al. (2011), are strikingly at odds with those observed by van Steenbergen et al. (2009, 2012) and Braem et al. (2013b). In those studies, congruency sequence effects were absent after reward, whereas here we see it increase. This marked difference likely stems from some important differences in experimental design. In van Steenbergen et al. (2009, 2012) or Braem et al. (2013b), feedback took the form of smiling or frowning schematic faces or positive or negative valence pictures that also indicated the receipt or loss of monetary value. Reward feedback thus had an affective and social importance that is absent in our design. Stimuli that induce positive affect have been found to increase task distractibility (Dreisbach & Goschke, 2004), and theoretical work on the motivation of adaptive behavior has suggested fundamental differences in the impact of affective versus reward feedback (Berridge & Robinson, 2003; Chiew & Braver, 2011). This raises the possibility that results from van Steenbergen et al. (2009, 2012) and Braem et al. (2013b) index the effect of emotional content rather than the motivational effect of reward, or, importantly, the emotional content of the negative stimuli. This observation is post hoc, but it highlights the need for systematic comparisons of the precise influence of affective versus reward feedback in conflict tasks (for a review, see Dreisbach & Fischer, 2012). Consistent with this proposal, an initial attempt at such a systematic comparison has recently shown decreased control following a positive mood induction, but increased control during a reward procedure (Fröber & Dreisbach, in press). However, other recent comparisons have demonstrated how noncontingent transient positive stimuli presentation can also promote control strategies (Braem et al., 2013b; Chiew & Braver, in press). There is a clear opportunity for further work designed to investigate the role of saliency, affectivity, baseline stimuli, performance-contingency, and transient versus sustained affective or motivational manipulations on cognitive control.

Cognitive adaptations to conflict like those detailed here seem likely to reflect the action of neuromodulatory mechanisms in the brain. In the adaptation-by-binding account, Verguts and Notebaert (2008, 2009) suggested that a nonselective Hebbian learning signal is sent throughout the brain. Verguts and Notebaert provisionally assign this role to the neurotransmitter norepinephrine. In contrast to this hypothesis, van Bochove, Van der Haegen, Notebaert, and Verguts (2013) demonstrated how adaptations to conflict varied as a function of eyeblink behavior, as a measure of dopaminergic activity, but not pupil dilation, as a measure of norepinephrine activity. Moreover, in line with this idea, Duthoo et al. (2013) demonstrated how dopaminergic medication determined if Parkinson's disease patients adapted to conflict or not. By contrasting Stroop task behavior once on medication, once following overnight withdrawal, Duthoo and colleagues demonstrated how the Gratton effect persisted following overnight withdrawal, but was absent on dopaminergic medication. These results were interpreted in terms of a dopamine overdose hypothesis (Coobs & D'Esposito, 2011). According to this the medication may have overdosed relatively preserved brain regions in Parkinson's disease patients, such as the ventral striatum and prefrontal cortex, thereby impeding adaptations to conflict. Finally,

Brown, van Steenberg, Kedar, and Nieuwenhuis (2014) have recently used measures of pupil dilation to systematically investigate the influence of arousal on conflict-induced adaptations. This work provides no evidence for modulatory effects of arousal. While these studies offer some first interesting insights in the possible primary neurotransmitters responsible for conflict control, more studies are needed to unfold the precise neurotransmitter functions essential for adaptations to conflict.

As noted in the Method section, the current study differed from earlier visual search studies in that we did not instruct participants to keep their eyes fixated on the center of the screen. As this reflects an important procedural difference, its impact should be taken into account when comparing our results to previous findings in the visual search literature. For example, it is possible that context alternations induced more eye-movements than context repetitions in the current results. Indeed, in Experiment 2, response latencies were enhanced for context alternations relative to context repetitions, which might be related to the oculomotor capture of the eyes to the distractor shape (e.g., Hickey & van Zoest, 2013; Theeuwes, De Vries, & Godijn, 2003). Unfortunately, we did not collect eye-movement data, and our results thus do not speak directly to this issue. There is clear room for dedicated work investigating the differential impact of context sequence on eye movements and possible consequences of such on the congruency sequence effect.

In conclusion, we demonstrate that reward has an impact on visual context that can determine the scope of cognitive control. We believe that this reflects an underlying role for reward in the control of attentional selection, directly influencing conflict adaptation processes. The type of mechanism identified in these results has a clear evolutionary benefit, guiding cognitive processing in favor of approaches and mechanisms that have garnered good outcome in the past. Reward—and its absence—clearly plays an important role in determining perception, attention, and cognitive control.

## References

- Anderson, B. A. (2013). A value-driven mechanism of attentional selection. *Journal of Vision, 13*, 7. doi:10.1167/13.3.7
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2011a). Learned value magnifies salience-based attentional capture. *PLoS ONE, 6*, e27926. doi:10.1371/journal.pone.0027926
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2011b). Value-driven attentional capture. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 108*, 10367–10371. doi:10.1073/pnas.1104047108
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2012). Generalization of value-based attentional priority. *Visual Cognition, 20*, 647–658. doi:10.1080/13506285.2012.679711
- Anderson, B. A., & Yantis, S. (2013). Persistence of value-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance, 39*, 6. doi:10.1037/a0030860
- Beaver, J. D., Lawrence, A. D., van Dithuijzen, J., Davis, M. H., Woods, A., & Calder, A. J. (2006). Individual differences in reward drive predict neural responses to images of food. *The Journal of Neuroscience, 26*, 5160–5166. doi:10.1523/JNEUROSCI.0350-06.2006
- Berridge, K. C., & Robinson, T. E. (2003). Parsing reward. *Trends in Neuroscience, 26*, 507–513. doi:10.1016/S0166-2236(03)00233-9
- Blais, C., Robidoux, S., Risko, E. F., & Besner, D. (2007). Item-specific adaptation and the conflict-monitoring hypothesis: A computational model. *Psychological Review, 114*, 1076–1086. doi:10.1037/0033-295X.114.4.1076
- Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*, 624–652. doi:10.1037/0033-295X.108.3.624
- Braem, S., Duthoo, W., & Notebaert, W. (2013a). Punishment sensitivity predicts the impact of punishment on cognitive control. *PLoS ONE, 8*, e74106. doi:10.1371/journal.pone.0074106
- Braem, S., King, J. A., Korb, F. M., Krebs, R. M., Notebaert, W., & Egner, T. (2013b). Affective modulation of cognitive control is determined by performance-contingency and mediated by ventromedial prefrontal and cingulate cortex. *The Journal of Neuroscience, 33*, 16961–16970. doi:10.1523/JNEUROSCI.1208-13.2013
- Braem, S., Verguts, T., & Notebaert, W. (2011). Conflict adaptation by means of associative learning. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 1662–1666. doi:10.1037/a0024385
- Braem, S., Verguts, T., Roggeman, C., & Notebaert, W. (2012). Reward modulates adaptations to conflict. *Cognition, 125*, 324–332. doi:10.1016/j.cognition.2012.07.015
- Brown, S. B., van Steenberg, H., Kedar, T., & Nieuwenhuis, S. (2014). Effects of arousal on cognitive control: Empirical tests of the conflict-modulated Hebbian-learning hypothesis. *Frontiers in Human Neuroscience, 8*, 23. doi:10.3389/fnhum.2014.00023
- Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS scales. *Journal of Personality and Social Psychology, 67*, 319–333. doi:10.1037/0022-3514.67.2.319
- Chiew, K. S., & Braver, T. S. (2011). Positive affect versus reward: Emotional and motivational influences on cognitive control. *Frontiers in Psychology, 2*, 279. doi:10.3389/fpsyg.2011.00279
- Chiew, K. S., & Braver, T. S. (in press). Dissociable influences of reward motivation and positive emotion on cognitive control. *Cognitive, Affective & Behavioral Neuroscience*.
- Colzato, L. S., van Wouwe, N. C., & Hommel, B. (2007). Feature binding and affect: Emotional modulation of visuo-motor integration. *Neuropsychologia, 45*, 440–446. doi:10.1016/j.neuropsychologia.2006.06.032
- Cools, R., & D'Esposito, M. (2011). Inverted-U-shaped dopamine actions on human working memory and cognitive control. *Biological Psychiatry, 69*, e113–e125.
- Davelaar, E. J., & Stevens, J. (2009). Sequential dependencies in the Eriksen flanker task: A direct comparison of two competing accounts. *Psychonomic Bulletin & Review, 16*, 121–126. doi:10.3758/PBR.16.1.121
- Della Libera, C., & Chelazzi, L. (2006). Visual selective attention and the effects of monetary rewards. *Psychological Science, 17*, 222–227. doi:10.1111/j.1467-9280.2006.01689.x
- Della Libera, C., & Chelazzi, L. (2009). Learning to attend and to ignore is a matter of gains and losses. *Psychological Science, 20*, 778–784. doi:10.1111/j.1467-9280.2009.02360.x
- Duthoo, W., Braem, S., Houtman, F., Schoupe, N., Santens, P., & Notebaert, W. (2013). Dopaminergic medication counteracts conflict adaptation in patients with Parkinson's disease. *Neuropsychology, 27*, 556–561.
- Dreisbach, G., & Fischer, R. (2012). The role of affect and reward in the conflict-triggered adjustment of cognitive control. *Frontiers in Human Neuroscience, 6*, 342.
- Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 343–353. doi:10.1037/0278-7393.30.2.343
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*, 143–149. doi:10.3758/BF03203267
- Fischer, R., Plessow, F., Kunde, W., & Kiesel, A. (2010). Trial-to-trial modulations of the Simon effect in conditions of attentional limitations:



- Evidence from dual tasks. *Journal of Experimental Psychology: Human Perception and Performance*, 36, 1576–1594. doi:10.1037/a0019326
- Franken, I. H. A., Muris, P., & Rassin, E. (2005). Psychometric properties of the Dutch BIS/BAS Scales. *Journal of Psychopathology and Behavioral Assessment*, 27, 25–30. doi:10.1007/s10862-005-3262-2
- Fröber, K. & Dreisbach, G. (in press). The differential influence of positive affect, random reward, and performance-contingent reward on cognitive control. *Cognitive, Affective, and Behavioral Neuroscience*.
- Gratton, G., Coles, M. G., & Donchin, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General*, 121, 480–506. doi:10.1037/0096-3445.121.4.480
- Hickey, C., Chelazzi, L., & Theeuwes, J. (2010a). Reward changes salience in human vision via the anterior cingulate. *Journal of Neuroscience*, 30, 11096–11103. doi:10.1523/JNEUROSCI.1026-10.2010
- Hickey, C., Chelazzi, L., & Theeuwes, J. (2010b). Reward guides vision when it's your thing: Trait Reward-Seeking in Reward-Mediated Visual Priming. *PLoS ONE*, 5, e14087. doi:10.1371/journal.pone.0014087
- Hickey, C., Chelazzi, L., & Theeuwes, J. (2011). Reward has a residual impact on target selection in visual search, but not on the suppression of distractors. *Visual Cognition*, 19, 117–182. doi:10.1080/13506285.2010.503946
- Hickey, C., McDonald, J. J., & Theeuwes, J. (2006). Electrophysiological evidence of the capture of visual attention. *Journal of Cognitive Neuroscience*, 18, 604–613. doi:10.1162/jocn.2006.18.4.604
- Hickey, C., & van Zoest, W. (2012). Reward creates oculomotor salience. *Current Biology*, 22, R219–R220. doi:10.1016/j.cub.2012.02.007
- Hickey, C., & van Zoest, W. (2013). Reward-associated stimuli capture the eyes in spite of strategic attentional set. *Vision Research*, 92, 67–74. doi:10.1016/j.visres.2013.09.008
- Hommel, B., Proctor, R. W., & Vu, K.-P. L. (2004). A feature-integration account of sequential effects in the Simon task. *Psychological Research*, 68, 1–17. doi:10.1007/s00426-003-0132-y
- Jiang, H., & Xu, B. (in press). Reward enhances backward inhibition in task switching. *Journal of Cognitive Psychology*.
- Kelley, A. E. (2004). Ventral striatal control of appetitive motivation: Role in ingestive behaviour and reward-related learning. *Neuroscience and Biobehavioral Reviews*, 27, 765–776. doi:10.1016/j.neubiorev.2003.11.015
- Kerns, J. G., Cohen, J. D., MacDonald III., A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science*, 303, 1023–1026. doi:10.1126/science.1089910
- Lorch, R. F., Jr., & Myers, J. L. (1990). Regression analyses of repeated measures data in cognition research. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 149–157. doi:10.1037/0278-7393.16.1.149
- Mordkoff, J. T. (2012). Three reasons to avoid having half of the trials be congruent in a four-alternative forced-choice experiment on sequential modulation. *Psychonomic Bulletin & Review*, 19, 750–757. doi:10.3758/s13423-012-0257-3
- Muhle-Karbe, P. S., & Krebs, R. M. (2012). On the influence of reward on action-effect binding. *Frontiers in Psychology*, 3, 450. doi:10.3389/fpsyg.2012.00450
- Notebaert, W., & Verguts, T. (2007). Dissociating conflict adaptation from feature integration: A multiple regression account. *Journal of Experimental Psychology: Human Perception and Performance*, 33, 1256–1260. doi:10.1037/0096-1523.33.5.1256
- Raymond, J. E., & O'Brien, J. L. (2009). Selective visual attention and motivation: The consequences of value learning in an attentional blink task. *Psychological Science*, 20, 981–988. doi:10.1111/j.1467-9280.2009.02391.x
- Reynolds, J. N. J., Hyland, B. I., & Wickens, J. R. (2001). A cellular mechanism of reward-related learning. *Nature*, 413, 67–70. doi:10.1038/35092560
- Robbins, T. W., & Everitt, B. J. (1996). Neurobehavioural mechanisms of reward and motivation. *Current Opinion in Neurobiology*, 6, 228–236. doi:10.1016/S0959-4388(96)80077-8
- Rutherford, H. J., O'Brien, J. L., & Raymond, J. E. (2010). Value associations of irrelevant stimuli modify rapid visual orienting. *Psychonomic Bulletin & Review*, 17, 536–542. doi:10.3758/PBR.17.4.536
- Satterthwaite, T. D., Ruparel, K., Loughhead, J., Elliott, M. A., Gerraty, R. T., Calkins, M. E., . . . Wolf, D. H. (2012). Being right is its own reward: Load and performance related ventral striatum activation to correct responses during a working memory task in youth. *NeuroImage*, 61, 723–729. doi:10.1016/j.neuroimage.2012.03.060
- Scherbaum, S., Dshemuchadse, M., Ruge, H., & Goschke, T. (2012). Dynamic goal states: Adjusting cognitive control without conflict monitoring. *NeuroImage*, 63, 126–136. doi:10.1016/j.neuroimage.2012.06.021
- Schultz, W. (2002). Getting formal with dopamine and reward. *Neuron*, 36, 241–263. doi:10.1016/S0896-6273(02)00967-4
- Schultz, W. (2004). Neural coding of basic reward terms of animal learning theory, game theory, microeconomics and behavioural ecology. *Current Opinion in Neurobiology*, 14, 139–147. doi:10.1016/j.conb.2004.03.017
- Silvetti, M., Alexander, W., Verguts, T., & Brown, J. W. (in press). From conflict management to reward-based decision making: Actors and critics in primate medial frontal cortex. *Neuroscience and Biobehavioral Reviews*. doi:10.1016/j.neubiorev.2013.11.003
- Simon, J. R. (1969). Reaction toward the source of stimulation. *Journal of Experimental Psychology*, 81, 174–176. doi:10.1037/h0027448
- Skinner, B. F. (1953). *Science and human behavior*. New York, NY: Macmillan.
- Spapé, M. M., & Hommel, B. (2008). He said, she said: Episodic retrieval induces conflict adaptation in an auditory Stroop task. *Psychonomic Bulletin & Review*, 15, 1117–1121. doi:10.3758/PBR.15.6.1117
- Steven, M., Lammertyn, J., Verbruggen, F., & Vandierendonck, A. (2006). Tscope: A C library for programming cognitive experiments on the MS Windows platform. *Behavior Research Methods*, 38, 280–286. doi:10.3758/BF03192779
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643–662. doi:10.1037/h0054651
- Stürmer, B., Leuthold, H., Soetens, E., Schröter, H., & Sommer, W. (2002). Control over location-based response activation in the Simon task: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 1345–1363. doi:10.1037/0096-1523.28.6.1345
- Stürmer, B., Nigbur, R., Schacht, A., & Sommer, W. (2011). Reward and punishment effects on error processing and conflict control. *Frontiers in Psychology*, 2, 335. doi:10.3389/fpsyg.2011.00335
- Theeuwes, J. (1991). Cross-dimensional perceptual selectivity. *Perception & Psychophysics*, 50, 184–193. doi:10.3758/BF03212219
- Theeuwes, J., De Vries, G. J., & Godijn, R. (2003). Attentional and oculomotor capture with static singletons. *Perception & Psychophysics*, 65, 735–746. doi:10.3758/BF03194810
- Thorndike, E. L. (1911). *Animal intelligence*. New York, NY: Macmillan.
- van Bochove, M. E., Van der Haegen, L., Notebaert, W., & Verguts, T. (2013). Blinking predicts enhanced cognitive control. *Cognitive, Affective & Behavioral Neuroscience*, 13, 346–354. doi:10.3758/s13415-012-0138-2
- van Steenbergen, H., Band, G. P. H., & Hommel, B. (2009). Reward counteracts conflict adaptation: Evidence for a role of affect in executive control. *Psychological Science*, 20, 1473–1477. doi:10.1111/j.1467-9280.2009.02470.x
- van Steenbergen, H., Band, G. P. H., & Hommel, B. (2012). Reward valence modulates conflict-driven attentional adaptation: Electrophysi-

- ological evidence. *Biological Psychology*, *90*, 234–241. doi:10.1016/j.biopsycho.2012.03.018
- Verguts, T., & Notebaert, W. (2008). Hebbian learning of cognitive control: Dealing with specific and nonspecific adaptation. *Psychological Review*, *115*, 518–525. doi:10.1037/0033-295X.115.2.518
- Verguts, T., & Notebaert, W. (2009). Adaptation by binding: A learning account of cognitive control. *Trends in Cognitive Sciences*, *13*, 252–257. doi:10.1016/j.tics.2009.02.007
- Waszak, F., & Pholulamdeth, V. (2009). Episodic S-R bindings and emotion: About the influence of positive and negative action effects on stimulus-response associations. *Experimental Brain Research*, *194*, 489–494. doi:10.1007/s00221-009-1745-1
- Wolfe, J. M., Butcher, S. J., Lee, C., & Hyle, M. (2003). Changing your mind: on the contributions of top-down and bottom-up guidance in visual search for feature singletons. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(2), 483.

Received October 15, 2012

Revision received June 16, 2014

Accepted June 17, 2014 ■