ORIGINAL RESEARCH REPORT

Biasing Actions by Incentive Valence in an Approach/Avoidance Task

Vincent Hoofs, C. Nico Boehler and Ruth M. Krebs

The present study investigates interactions between incentive valence and action, which mirror well-known valence-action biases in the emotional domain. In three joystick experiments, incentive valence (win/loss) and action type (approach/avoid) were signaled by distinct orthogonal stimulus features. By combining several design aspects, i.e., the use of bi-directional joystick movements, the inclusion of no-incentive baseline trials, and cue-locked versus target-locked valence and action signals, we tried to bridge between paradigms used in the emotional and motivational domain, and to understand previous, partly inconsistent results. In the first task variant (Experiment 1), we observed performance benefits for compatible mappings (win-approach; loss-avoid) relative to incompatible ones (loss-approach; win-avoid) when valence and action signals were target-locked, consistent with a fairly automatic response activation that can benefit or impair task performance. In contrast, cue-locked valence signals led to response facilitation (relative to a no-incentive baseline) more or less independent of actual valence (win/loss) and action type (approach/avoid), which is reminiscent of general facilitation effects of incentive cues across diverse cognitive tasks. Slight design variations did not change this main result pattern, indicating that it was neither driven by the close proximity between target and performance feedback (Experiment 2), nor by mere temporal coincidence of valence and action signals (Experiment 3), but rather by differences between preparatory (cued) and immediate (non-cued) effects of incentive valence. The present study provides novel insights regarding the nature of valence-action biases in the motivational domain and helps to integrate previous, partly inconsistent findings across domains.

Keywords: valence-action bias; incentive valence; win/loss; reward; action; approach/avoidance

Introduction

Reaching towards a tasteful cookie and backing off from a spider is evidently easier than performing the opposite actions when facing these stimuli. This phenomenon, which has been described as valence-action bias (Elliot, 2006; Phaf, Mohr, Rotteveel, & Wicherts, 2014; Solarz, 1960), is thought to arise from a fairly automatic evaluation of a given stimulus, which in turn triggers inherent approach and avoidance tendencies (Bargh, Chaiken, Raymond, & Hymes, 1996; Chen & Bargh, 1999; Kozlik, Neumann, & Lozo, 2015). However, there is also work suggesting a more indirect link between valence and action relying on more conscious appraisal (Phaf et al., 2014; Rotteveel & Phaf, 2004). Regardless of the exact nature of these mappings between valence and action, there is consensus on the view that they play an important role in energizing and directing our behavior (Elliot & Covington, 2001; Elliot, 2006).

Valence-action biases, as indexed by performance facilitation of compatible mappings (positive-approach; negative-avoid), have been most prominently reported for innate emotional stimuli and events that have to be approached or avoided (e.g., Chen & Bargh, 1999; Krieglmeyer, Deutsch, De Houwer, & De Raedt, 2010; Phaf et al., 2014; Seibt, Neumann, Nussinson, & Strack, 2008). In these studies, the valence dimension (ranging from positive to negative) of emotional information is actively manipulated, while the arousal dimension (ranging from exciting to calming) along which emotional stimuli can vary as well (Kensinger & Corkin, 2004) is generally unchanged. More recent studies translated these types of paradigms into the motivational domain by introducing monetary incentive manipulations (wins and losses). While it has been argued that these different valence types are strongly related on the neural level and with regard to guiding participants' actions (Pessoa, 2008, 2009), studies investigating interactions between incentive valence and action seem to yield partly inconsistent findings. In a series of studies, Guitart-Masip and colleagues found valence-action biases in an incentive Go/NoGo task, in that participants' performance was improved in trials with

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compatible ('natural') mappings, i.e., Go-Win, NoGo-Avoid Losing (Guitart-Masip et al., 2011, 2012; Richter et al., 2014). In contrast, other recent studies manipulating incentives in Go/NoGo, Stop-signal, or approach/avoidance tasks failed to provide clear evidence for such valence-action biases (Boehler, Hopf, Stoppel, & Krebs, 2012; Hoofs, Carsten, Boehler, & Krebs, 2019; Schevernels, Bombeke, Krebs, & Boehler, 2016; Verbruggen & McLaren, 2016). This inconsistency probably results from paradigmatic differences. The first regards the exact composition of valence conditions. Specifically, while the paradigm applied by Guitart-Masip and colleagues (2011, 2012) contrasted win and loss incentives directly (and exclusively), more recent studies included no-incentive conditions as well. This was either done by adding no-incentive trials (Schevernels et al., 2016), by comparing win and loss trials to a no-incentive baseline in discrete groups (Hoofs et al., 2019), or by contrasting win, loss, and, no-incentive manipulations between groups (Verbruggen & McLaren, 2016). Consequentially, some of these studies did not feature a direct contrast between positive and negative valence. Second, the above tasks differed with regard to the exact response requirements, i.e., Go vs. NoGo (Guitart-Masip et al., 2011, 2012), Go vs. cancel a planned response (Boehler et al., 2012; Verbruggen & McLaren, 2016), and approach vs. avoid (Hoofs et al., 2019). Third, the tasks also differed in terms of valence-action signaling, with some using fixed valence-action stimuli (Guitart-Masip et al., 2011, 2012; Richter et al., 2014; Schevernels et al., 2016), orthogonal valence-action mappings (Boehler et al., 2012; Hoofs et al., 2019), and/or group-based manipulations (Hoofs et al., 2019; Verbruggen & McLaren, 2016). Last, the studies differed with regard to the relevant trial events in that valence was either linked to cues (Guitart-Masip et al., 2011, 2012; Richter et al., 2014; Schevernels et al., 2016) or targets (Boehler et al., 2012; Freeman, Razhas, & Aron, 2014), thereby tapping into preparatory and immediate control mechanisms, respectively (Krebs & Woldorff, 2017). This is particularly important considering that related studies in the emotional domain typically employed valence targets in the absence of pre-cues (e.g., Krieglmeyer et al., 2010). Moreover, the dissociation between cue-based and target-based manipulations also relates to differential (neural) effects of sustained and transient reward manipulations (Beck, Locke, Savine, Jimura, & Braver, 2010; Engelmann, Damaraju, Padmala, & Pessoa, 2009). Taken together, the inconsistencies in design and results across previous studies on incentive valence-action biases seem to call for further investigation.

With the present study we aimed to bridge between different types of paradigms to test under which circumstances incentive valence-action biases can occur, thereby also exploring the reasons for the rather inconsistent results of the earlier studies. To this end, we employed an incentive approach-avoidance paradigm that includes a novel combination of design features that have been implemented in different previous studies – both in the motivational and emotional domain. These features include changing valence-action combinations from trial-to-trial, the contrast between positive, negative, and no-incentive trials within-participants, and the use of approach/avoidance joystick movements that can be considered more natural as compared to button presses (and provide both speed and accuracy measures in all conditions). Moreover, we linked incentive valence (and action) signals to either cues or targets in discrete blocks in order to probe differential contributions from preparatory and immediate control processes.

Our first main hypothesis was that this novel experimental set-up should bring about incentive valence-action biases that are similar to the ones reported by previous approach-avoidance studies employing emotional stimuli (research question 1). This is based on the assumption that incentive valence and action requirements are integrated in terms of inherent response tendencies, which can induce performance benefits and costs when they are compatible (win-approach; loss-avoid) and incompatible (loss-approach; win-avoid), respectively. By associating valence and action signals to different trial events (cues and targets), we aimed to test a second hypothesis regarding the role of different 'control' processes (research question 2). Specifically, we hypothesized that valence-action biases would emerge when valence and action signals are directly associated with a target stimulus (due to more immediate, automatic processes), and be less pronounced when they are signaled by advance cues (which should promote preparatory, strategic processes). To test these hypotheses, we focused on the presence/absence of valence-action biases as indexed by an interaction between valence and action type (research question 1), and in how far this interaction would be further modulated by the association with different trial events (i.e., target-locked/cue-locked) as indexed by a 3-way interaction with block type (research question 2).

To briefly preview the results, in line with our hypotheses, we observed robust valence-action biases across three task variants when valence and action were signaled by the target, and general performance facilitation in incentive as compared to no-incentive trials when they were signaled by advance cues.

Methods and results
Methods Experiment 1
Participants
Forty-seven students from Ghent University participated in Experiment 1 (34 females, mean age ± SD: 23.3 ± 3.3 years, age range 18–35 years). Data from one additional (male) participant were excluded due to high error rates (>3.0 SD from the group mean). Prerequisites for participation were age between 18 and 35 years, right-handedness, normal color perception, normal or corrected-to-normal vision, and no (history of) diagnosed mental disorders. Experimental procedures were approved by the local ethics board, and written informed consent was obtained from each participant upon arrival. Participants received a basis reimbursement of 10 euro for the 60-minute session, and a maximum monetary reward of 3 euro based on task performance in incentive trials (average bonus = 1.82 euro).

Paradigm and procedure

Participants performed an incentivized cued approach/avoidance task in which pushing and pulling of a joystick was associated with movements of a manikin on the computer screen. Each trial contained a cue, a target, and a feedback event. The required action (approach, avoid) was indicated by vertical vs. horizontal target orientation (counterbalanced across participants). Incentive valence of a trial (win, loss, no-incentive) was signaled by distinct colors drawn from a set of four colors (i.e., orange RGB = 238, 91, 18; blue RGB = 50, 138, 255; pink RGB = 230, 10, 200; green RGB = 27, 158, 23). The two remaining colors were both linked to no-incentive information. Hence, 50% of all trials were no-incentive trials featuring two different colors to prevent for asymmetries regarding color proportions between incentive and no-incentive conditions (for similar procedure see Carsten, Hoofs, Boehler, & Krebs, 2019). All (no-)incentive-color mappings were counterbalanced across participants. Importantly, these colors could occur in either the cue or target stimulus in different block types (cue-valence, target valence blocks). The respective other trial event was always presented in gray (RGB = 139, 139, 139). After four practice

trials of joystick movements (two for each orientation), participants were explicitly instructed about the incentive-color mapping. Next, half of the participants practiced eight cue-valence trials (two of each valence color) and subsequently performed the first cue-valence block, while the other half practiced eight target-valence trials and performed the first target-valence block. After the first experimental block, participants practiced the respective other block type before starting the next experimental block. From block three onwards, experimental blocks were not preceded by practice trials anymore. Exemplary trials are depicted in **Figure 1**. During all trials, a white fixation cross and white place holder (diameter = 4.2° visual angle) were visible in the upper half of the screen. Each trial started with the presentation of a square-shaped cue in the place holder for 200 ms. After a random interval between 500 ms and 1500 ms after cue offset, an ellipse shaped target appeared in the place holder, accompanied by a manikin in the lower half of the screen (distance to target = 5.7° visual angle). Dependent on the current block type, either cues or targets were colored to signal incentive valence. Participants had to perform the correct action within a certain time window after target
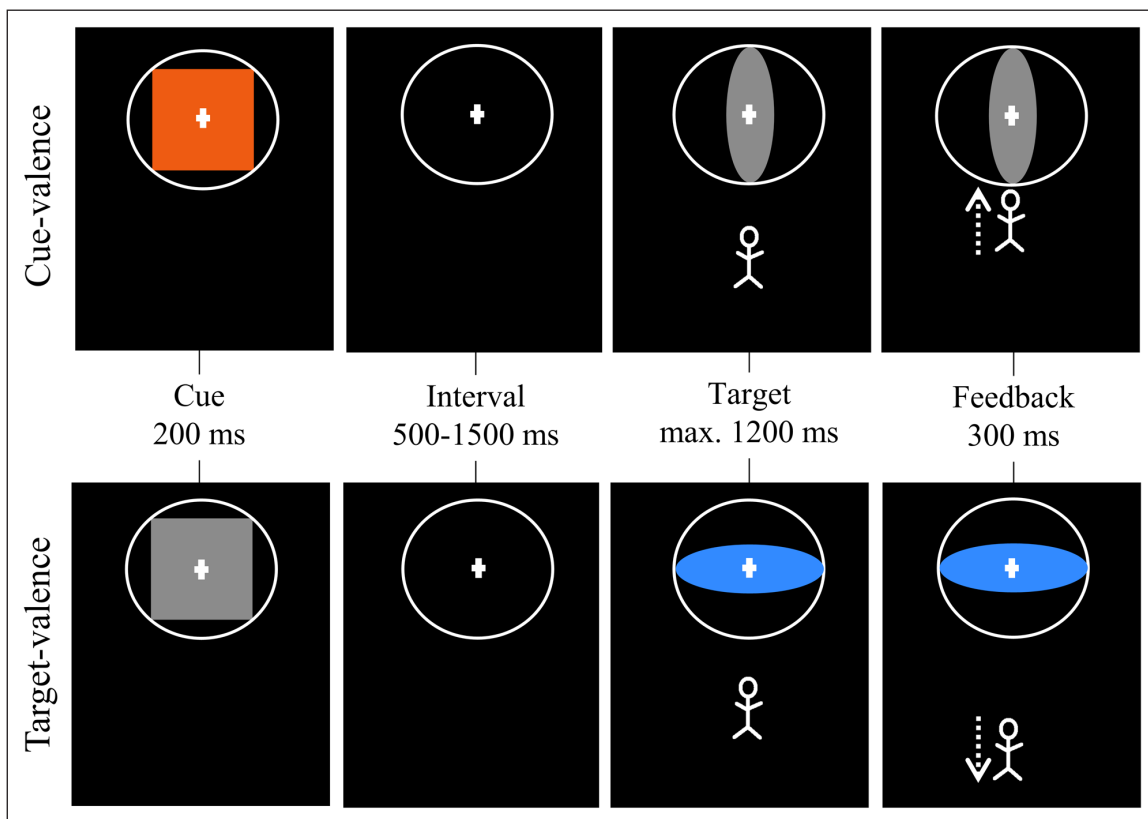
Figure 1: Schematic depiction of trials in cue-valence (top) and target-valence blocks (bottom) in Experiment 1. Each trial started with the presentation of a square-shaped cue. In cue-valence blocks, incentive valence (win/loss/no-incentive) was signaled by cue color (with all targets in gray), while in target-valence blocks, valence was signaled by target color (with all cues presented in gray). Targets had to be approached (push) or avoided (pull) depending on their orientation (the upper panel shows an example of an approach trial, the lower panel displays an avoid trial). Feedback was provided directly upon response, indicating whether the response was correct and in-time (i.e., action-congruent movement of the manikin, here indicated by dotted arrow), incorrect (i.e., white cross), or too late (i.e., white clock).

onset to win or avoid losing incentives (see below). Targets stayed on the screen until a response was given, or for a maximum interval of 1200 ms. Correct and in-time responses were directly followed by response-congruent movements of the manikin (towards or away from the target), serving as 'correct-feedback', while incorrect or late responses led to the disappearance of the target and presentation of a white cross or white clock in the placeholder, respectively. All types of feedback lasted for 300 ms, and after a random interval between 1500 ms and 3000 ms after feedback offset, the next trial was presented (**Figure 1**). In order to ensure comparable overall incentive probabilities, response windows were dynamically adjusted for each condition on the basis of participants' individual performance (Cornsweet, 1962; for similar procedures, see Carsten et al., 2019; Hoofs et al., 2019). This procedure was set to yield 80% correct feedback per experimental condition. Participants would receive a 2-ct gain for correct and in-time responses in win trials, and incur a 2-ct loss for incorrect/too-late responses in loss trials. Importantly, irrespective of the dynamic response window and titrated feedback rate, all responses in a fixed response window between 150 ms and 1200 ms after target onset were included in the analyses. Specifically, responses exceeding the dynamically adjusted time window of a given condition were followed by too-late feedback, but were still analyzed if they fell within the pre-set response window of 150–1200 ms. Each block ended with an overview of the participants' performance, showing the percentage of correct and in-time responses, and the amount of money earned so far (both based on the titrated feedback). Trials were divided over four blocks of 152 trials, which each contained cue-valence or target-valence trials only. Cue-valence and target-valence blocks were alternated ('ABAB'), with half of the participants starting with a cue-valence block and the other half with a target-valence block. Conditions were formed by combining all three experimental factors, i.e., Block type (cue-valence/target-valence), Valence (win/loss/no-incentive), and Action (approach/avoid). The paradigm entailed 38 trials per condition for win trials, 38 trials per condition for loss trials, and 76 trials per condition for no-incentive trials (collapsed across two no-incentive colors).

Data analyses

Analysis procedures are the same across all experiments. All premature responses (defined as response times <150 ms) were excluded from the dataset first. Next, response times (correct trials only) and error rates (in-time responses irrespective of the adaptive time-out procedure) were submitted to $3 \times 2 \times 2$ repeated-measures analyses of variance (rANOVAs), with within-subject factors *Valence* (win/loss/no-incentive), *Action* (approach/avoid), and *Block type* (cue-valence/target-valence). A Greenhouse-Geisser correction was applied when the sphericity assumption was violated, and the p-values of post-hoc contrasts were corrected for the rational amount of possible comparisons by using Bonferroni corrections (for more information see page 1 of the Supplement Material). Please note that the effect size Cohen's *d* reported for

the post-hoc contrasts does not correct for multiple comparisons. Our main interest was the presence of valence-action biases as indexed by an interaction between Valence and Action (research question 1), and in how far such effects would be further modulated by Block type as indexed by a 3-way interaction between Valence, Action, and Block type (research question 2). In case the analysis revealed a Valence × Action interaction in the absence of a 3-way interaction, we performed post-hoc contrasts based on the 2-way interaction. In case of a significant 3-way interaction, we report post-hoc contrasts for the higher-order interaction. Further, we will describe significant main effects in the results sections of the individual experiments for completeness, but refer to the Supplement Material (Table S1) for other 2-way interactions that are not in the focus of this study. Finally, in the context of these interactions, we define valence-action biases as opposing effects of positive and negative valence on approach and avoidance actions. No-incentive trials are included to illustrate global performance facilitation (or impairment) due to incentive valence that may occur independent of the bias.

Results Experiment 1

Response times

Mean response times are depicted in **Figure 2A**. The analysis revealed a main effect of Valence ($F(2, 92) = 41.33$, $p < .001$; $\eta^2_p = .473$), with faster responses in incentive as compared to no-incentive trials (win vs. no-incentive: $t(46) = -8.51$, $p$corr $< .001$; $d = -1.241$; loss vs. no-incentive: $t(46) = -6.31$, $p$corr $< .001$; $d = -0.920$), but no significant difference between win and loss trials ($p$corr $> .1$). Further, responses were generally faster in approach as compared to avoid trials (Action: $F(1, 46) = 19.53$, $p < .001$; $\eta^2_p = .298$), and faster in cue-valence blocks as compared to target-valence blocks (Block type: $F(1, 46) = 14.44$, $p < .001$; $\eta^2_p = .239$). With regard to our first research question, we observed the expected interaction between Valence and Action ($F(2, 92) = 13.60$, $p < .001$; $\eta^2_p = .228$), which was further qualified by a significant 3-way interaction (Valence × Action × Block type: $F(2, 92) = 4.34$, $p = .016$; $\eta^2_p = .086$), and therefore followed up by post-hoc contrasts. First, focusing on target-valence blocks, we observed response acceleration when targets had to be approached in win compared to both loss trials ($t(46) = -2.88$, $p$corr $= .018$; $d = -0.421$) and no-incentive trials ($t(46) = -5.71$, $p$corr $< .001$; $d = -0.833$), as well as for loss compared to no-incentive trials ($t(46) = -2.60$, $p$corr $= .038$; $d = -0.379$). In contrast, when targets had to be avoided, we found response slowing for win as compared to loss trials ($t(46) = 2.95$, $p$corr $= .015$; $d = 0.431$) and response acceleration in loss compared to no-incentive trials ($t(46) = -2.81$, $p$corr $= .022$; $d = -0.410$). The difference between win and no-incentive trials was not significant ($p$corr > 1). As expected based on the 3-way interaction including Block type, we found a different pattern in the cue-valence blocks. Specifically, when targets had to be approached, responses were again faster in win compared to loss trials ($t(46) = -3.32$, $p$corr $= .005$; $d = -0.484$) and no-incentive trials ($t(46) = -8.41$, $p$corr $< .001$; $d = -1.226$), and also in loss compared to
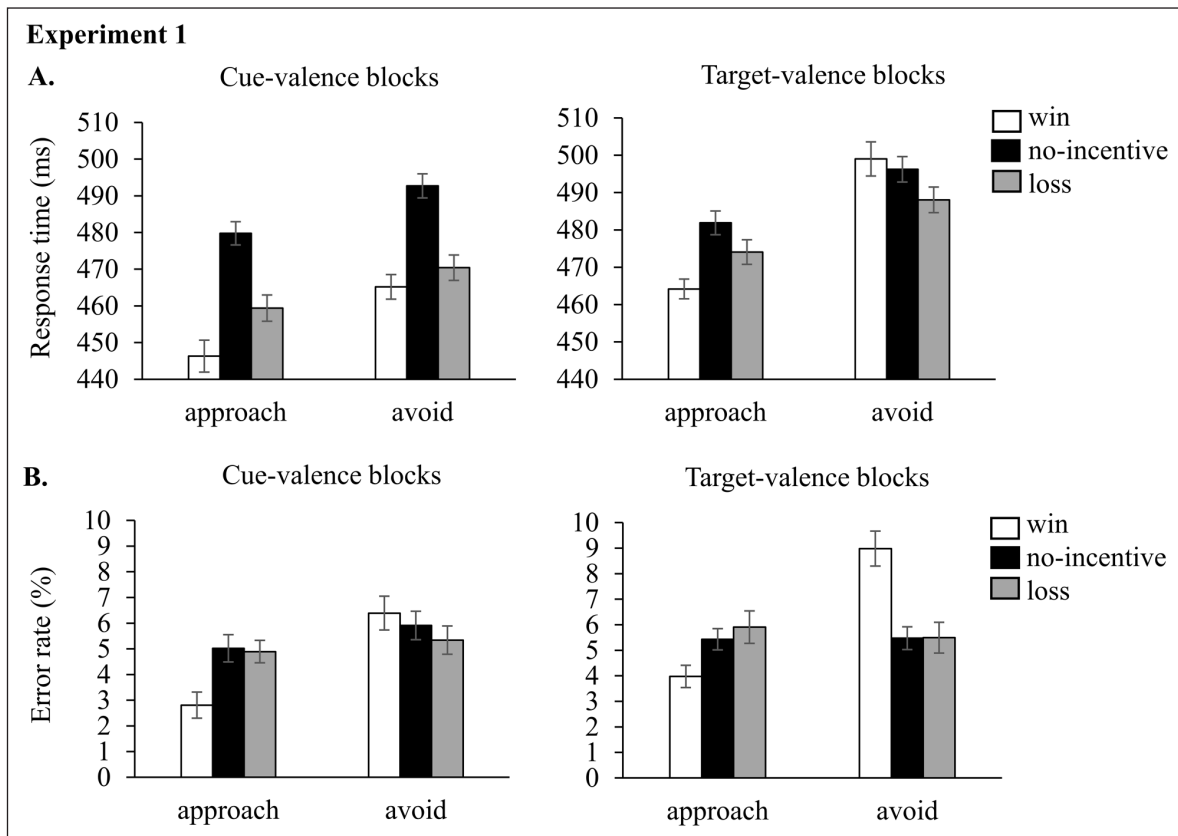
Figure 2: Response times **(A)** and error rates **(B)** corresponding to cue-valence blocks *(left)* and target-valence blocks *(right)* for the different types of Valence (win/no-incentive/loss) and Action (approach/avoid) in Experiment 1. *Error bars* indicate ± one within-subject standard error (Cousineau, 2005).

no-incentive trials ($t(46) = -5.71$, $p$corr < .001; $d = -0.832$). In the avoid condition, we found significantly faster responses in both win trials ($t(46) = -7.60$, $p$corr < .001; $d = -1.108$) and loss trials ($t(46) = -5.72$, $p$corr < .001; $d = -0.834$) when compared to no-incentive trials, but no difference between win and loss incentives ($p$corr > .3). Together, the results indicate that expected valence-action biases were only observed in target-valence blocks, while cue-valence blocks featured a global facilitation based on both incentive types.

Error rates
Mean error rates are depicted in **Figure 2B**. There was no main effect of Valence in the error rate data ($p > .9$). Fewer errors were committed in approach as compared to avoid trials (Action: $F(1, 46) = 10.44$, $p = .002$; $\eta^2_p = .185$), as well as in cue-valence compared to target-valence trials (Block type: $F(1, 46) = 10.26$, $p = .002$; $\eta^2_p = .182$). Further, we observed a significant interaction between Valence and Action ($F(2, 92) = 18.98$, $p < .001$; $\eta^2_p = .292$), which was due to an increased error rate in incompatible as compared to compatible valence-action mappings, as revealed by post-hoc contrasts. Specifically, within the approach condition, participants committed fewer errors in win trials compared to loss trials ($t(46) = -3.74$, $p$corr = .002; $d = -0.546$) and no-incentive trials ($t(46) = -5.38$, $p$corr < .001; $d = -0.784$), with no difference between loss and no-incentive trials ($p$corr > 1). Conversely, within the avoid condition, more errors were committed in win trials compared to loss trials ($t(46) = 3.63$, $p$corr = .002;

$d = 0.529$) and no-incentive trials ($t(46) = 3.39$, $p$corr = .004; $d = 0.495$), with no difference between loss and no-incentive trials ($p$corr > 1). This pattern is consistent with the notion of incentive valence-action biases, where compatible and incompatible mappings lead to performance improvements and detriments, respectively. In contrast to the response time data, this pattern did not differ between Block types, as indexed by a non-significant 3-way interaction ($p > .3$).

Interim summary
In Experiment 1, we found valence-action biases in terms of response speed and accuracy, with performance facilitation for compatible (win-approach; loss-avoid) and impairment for incompatible valence-action mappings (loss-approach; win-avoid). In the response time data, these biases were moreover pronounced when valence was signaled by the target as compared to the cue. In contrast, both incentive cues led to global facilitation (faster responses) as compared to no-incentive trials. The differential effects of win versus loss incentives depending on action and block type in Experiment 1 are illustrated in the Supplement Material (Figure S1, Exp 1).

Methods Experiment 2
In the first experiment, responses were followed directly by performance feedback, which represent actual incentive outcomes (for correct and in-time responses). Given the typical succession of events, the effect of such immediate performance feedback might have affected

the data stronger in the valence-associated target blocks than in the valence-associated cue blocks due to the immediate temporal proximity of targets and feedback, hence potentially explaining the differences in result patterns of the block types. In a second experiment, we therefore introduced a systematic temporal delay between the target and feedback stimulus to test whether the amplification of the bias in target-valence relative to cue-valence blocks would be abolished or reduced when targets (and responses) are not directly followed by performance feedback.

Participants

An independent sample of forty-seven students participated in Experiment 2 (37 females, mean age ± SD: 21.6 ± 2.9 years, age range 18–28 years). Data from one additional (female) participant were excluded due to a technical problem (i.e., lost joystick connection). General procedures (including recruitment and ethical approval) were identical to Experiment 1, with the exception that a part of the students received a course credit (N = 18) while the others received a monetary reimbursement (10 Euro) for the 60-min session together with the earned monetary reward (average = 1.77 euro).

Paradigm and procedure

In this experiment, we inserted a variable temporal delay of 1000–2000 ms between the motor responses and feedback animations. In addition, to ensure that participants' arm positions during feedback presentation (arm extension/arm flexion) were not in accordance with the direction of the movement feedback on the screen, feedback was postponed as long as the joystick was not placed back within the start position range (i.e., in-between the positive and negative y-axis coordinates for response registration). As a consequence, 0.27% of all trials provided feedback after an interval exceeding the 2000 ms. Because of longer trial durations, blocks (128 trials) and conditions (32/64 trials) contained slightly lower amounts of trials compared to Experiment 1, while gains/losses were increased to 2.4-ct per incentive trial. In all other aspects, this Experiment was identical to Experiment 1. Data analysis and reporting of the results is equivalent to Experiment 1 (additional effects and contrasts are reported in the Supplement Material, Table S2).

Results Experiment 2

Response times

Mean response times are depicted in **Figure 3A**. Again, we observed a main effect of Valence ($F(2, 92) = 19.51$, $p < .001$; $\eta^2_p = .298$) with faster responses for incentive trials as compared to no-incentive trials (win vs. no-incentive: $t(46) = -5.35$, $p\text{corr} < .001$; $d = -0.780$; loss vs. no-incentive: $t(46) = -4.41$; $p\text{corr} < .001$; $d = -0.643$), but no global difference between win trials and loss trials ($p\text{corr} > .1$). Furthermore, responses were again faster in cue-valence as compared to target-valence blocks (Block
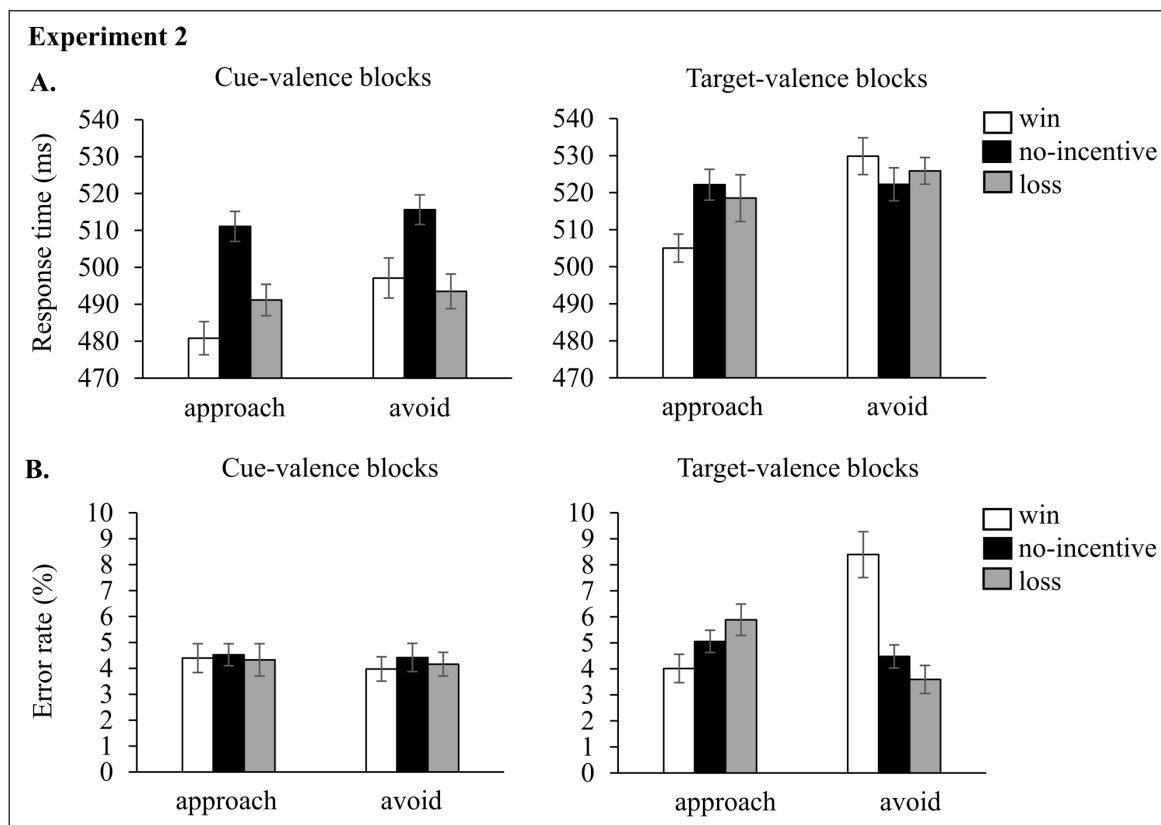
Figure 3: Response times **(A)** and error rates **(B)** corresponding to cue-valence blocks *(left)* and target-valence blocks *(right)* for the different types of Valence (win/no-incentive/loss) and Action (approach/avoid) in Experiment 2. *Error bars* indicate ± one within-subject standard error.

type: $F(1, 46) = 15.46$, $p < .001$; $\eta^2_p = .252$), and also numerically faster (at statistical trend level) in approach as compared to avoid trials (Action: $F(1,46) = 3.17$, $p = .081$; $\eta^2_p = .065$). Above and beyond these main effects, the analysis again revealed a significant interaction between Valence and Action ($F(1.76, 81.09) = 13.45$, $p < .001$; $\eta^2_p = .226$) that was driven by significantly faster responses within the approach condition for win trials than loss trials ($t(46) = -3.43$, $p$corr $= .004$; $d = -0.501$) and no-incentive trials ($t(46) = -7.30$, $p$corr $< .001$; $d = -1.065$). Moreover, approach responses in loss trials were also faster than in no-incentive trials ($t(46) = -3.64$, $p$corr $= .002$; $d = -0.531$). In the avoid condition, responses in loss trials were faster compared to no-incentive trials ($t(46) = -3.56$, $p$corr $= .003$; $d = -0.520$), while the remaining contrasts were not significant (both $p$corr $> .2$). This pattern did not differ between Block types as indicated by a non-significant 3-way interaction (Valence $\times$ Action $\times$ Block type: $p > .2$).

Error rates

Mean error rates are depicted in **Figure 3B**. Error rates were overall lower in cue-valence as compared to target-valence blocks (Block type: $F(1, 46) = 6.57$, $p = .014$; $\eta^2_p = .125$), while the main effects of Valence and Action were not significant in the error rate data (both $p > .2$). We again observed a significant Valence $\times$ Action interaction ($F(2, 92) = 6.89$, $p = .002$; $\eta^2_p = .130$), which was accompanied by a significant 3-way interaction with Block type ($F(1.41, 65.06) = 8.61$, $p = .002$; $\eta^2_p = .158$). In this experiment, the interaction was driven by higher error rates in win as compared to loss trials ($t(46) = 4.15$, $p$corr $< .001$; $d = 0.605$) and no-incentive trials ($t(46) = 3.83$, $p$corr $= .001$; $d = 0.559$) when targets had to be avoided. The remaining post-hoc contrasts did not reach significance (all $p$corr $> .1$).

Interim summary

Experiment 2 replicated the general observation of incentive valence-action biases, both in terms of response speed and accuracy. Moreover, the bias was again more pronounced when valence and action were signaled by the target, however, this interaction was now observed in the error rate data (see across-experiment analysis for further qualification). The differential effects of win versus loss incentives depending on action and block type in Experiment 2 are illustrated in the Supplement Material (Figure S1, Exp 2).

Methods Experiment 3

To further explore the nature of the observed valence-action biases, we tested whether the 3-way interaction between Valence, Action and Block type in Experiment 1 (response times) and Experiment 2 (error rates) might be due to the fact that during target-valence blocks, valence and action signals were presented simultaneously – irrespective of the associated event (here, target). In the third experiment, valence and action signals were hence always presented simultaneously, either bound to the cue or bound to the target. Note that although the cue manipulation is different as compared to Experiment 1

and 2 (in that the cue also includes action information), we will keep the same block labels (i.e., cue-valence and target-valence) for simplicity.

Participants

Another independent sample of forty students (31 females, mean age $\pm$ SD: 18.9 $\pm$ 0.9 years, age range 18–21) was recruited for Experiment 3. General procedures were identical to Experiment 1, except that all students received a course credit for the 60-min session, as well as their earned monetary reward (average bonus = 1.81 euro).

Paradigm and procedure

Participants again performed a similar version of the first experiment, with the major difference that both valence *and* action information were coupled to either cues or targets in discrete blocks. The respective other event only provided temporal information in that targets in cue-valence blocks signaled the moment of response execution, while cues in target-valence blocks signaled the start of the trial. The task is illustrated in **Figure 4**. Although the cue manipulation is different from Experiments 1 and 2, we will keep referring to the different block types as cue-valence blocks and target-valence blocks for simplicity. Cues and targets were shaped differently in cue-valence blocks (rectangles vs. circles) compared to target-valence blocks (squares vs. ellipses) in order to help participants to dissociate the block types. Since cues in this experiment could contain all the required information already, we endeavored to prevent participants from responding to these cues directly (i.e., before target presentation). To this end, an additional type of feedback was included in case the joystick position already exceeded the response threshold at the time of the target onset (*'te vroeg'*, meaning: 'too early'). Incorrect and late responses were followed by the words *'fout'* (i.e., error) and *'te laat'* (i.e., too late), respectively. In all other aspects, this experiment was identical to Experiment 1. Data analysis and reporting of the results is equivalent to Experiments 1 and 2 (additional effects and contrasts are reported in the Supplement Material, Table S3).

Results Experiment 3
Response times

Mean response times are depicted in **Figure 5A**. Like in Experiments 1 and 2, a main effect of Valence ($F(2, 78) = 21.73$, $p < .001$; $\eta^2_p = .358$) confirmed faster responses for win trials compared to loss trials ($t(39) = -3.76$, $p$corr $= .002$; $d = -0.594$) and no-incentive trials ($t(39) = -6.05$; $p$corr $< .001$; $d = -0.956$), and for loss trials compared to no-incentive trials ($t(39) = -3.28$, $p$corr $= .007$; $d = -0.519$). Further, a main effect of Block type ($F(1, 39) = 540.80$, $p < .001$; $\eta^2_p = .933$) indicated that responses in cue-valence blocks were faster than in target-valence blocks, consistent with the fact that a response could be fully prepared in this case. There was no main effect of Action in the response time data of this experiment ($p > .9$). The interaction between Valence and Action was marginally significant ($F(2, 78) = 2.99$, $p = .056$; $\eta^2_p = .071$). Post-hoc contrasts indicated response
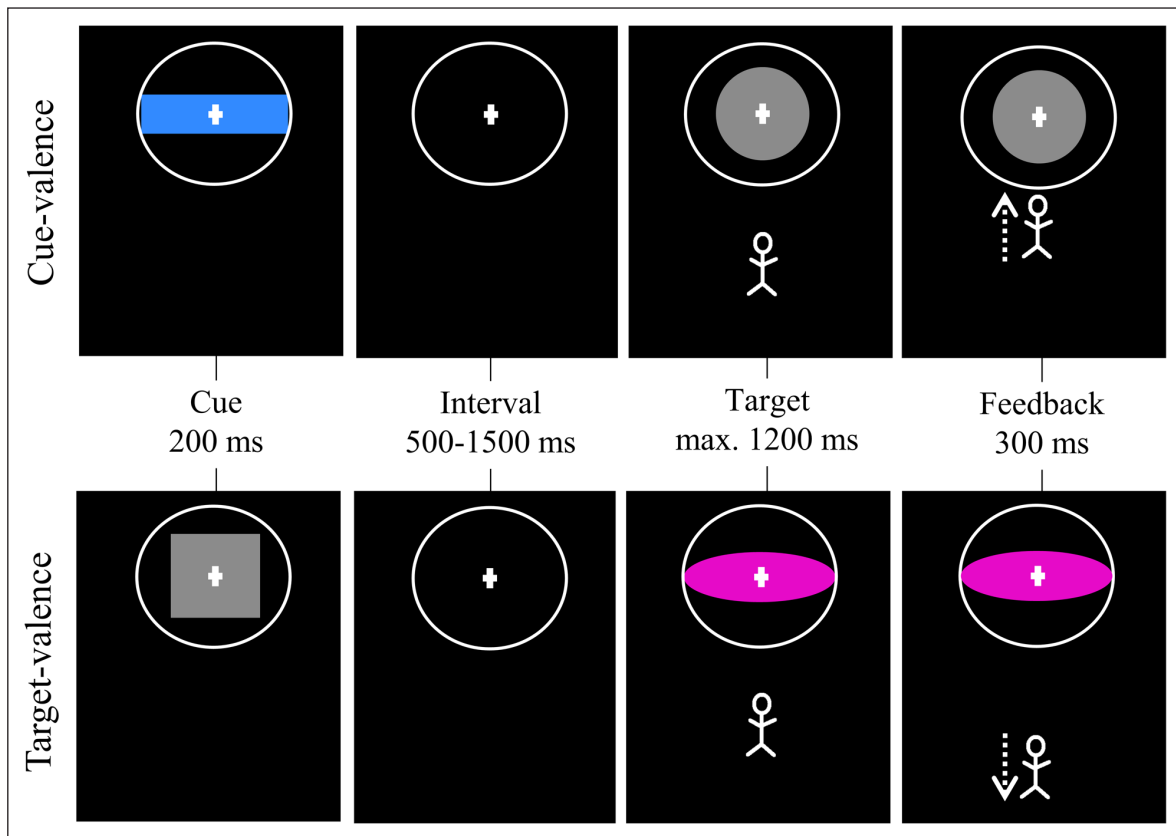
Figure 4: Schematic depiction of trials in cue-valence (top) and target-valence blocks (bottom) in Experiment 3. In contrast to Experiments 1 and 2, both valence *and* action information were linked to either the cues or the targets in discrete blocks. The respective other event (in grey) only provided temporal information in that targets in cue-valence blocks signaled the moment of response execution, while cues in target-valence blocks signaled the start of the trial. Although the cue manipulation in this experiment differs from the one applied in Experiment 1 and 2, we keep referring to the different block types as cue-valence blocks and target-valence blocks.

acceleration in win compared to loss trials ($t(39) = -4.06$; $p$corr < .001; $d = -0.642$) as well as no-incentive trials ($t(39) = -5.55$; $p$corr < .001; $d = -0.877$), but not for loss compared to no-incentive trials ($p$corr > .2) when targets had to be approached. The pattern was similar but less pronounced in avoid trials, with response acceleration in win as compared to no-incentive trials ($t(39) = -3.53$; $p$corr = .003; $d = -0.558$) as well as in loss compared to no-incentive trials ($t(39) = -3.16$; $p$corr = .009; $d = -0.500$), and no difference between win and loss trials ($p$corr > 1). The 3-way interaction between Valence, Action, and Block type in the response time data of this experiment was not significant ($p > .5$).
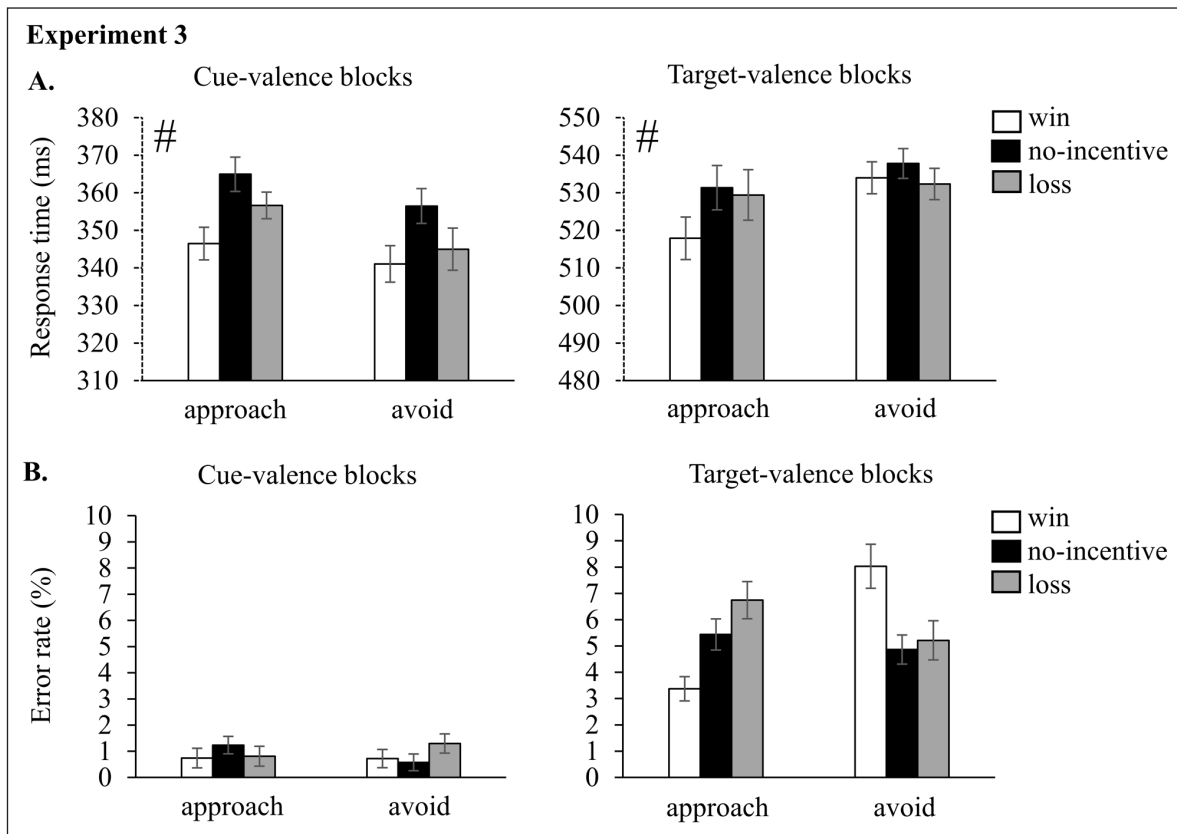
Error rates

Mean error rates are depicted in **Figure 5B**. The analysis again revealed an expected main effect of Block type ($F(1, 39) = 72.99$, $p < .001$; $\eta^2_p = .652$), with increased error rates in target-valence as compared to cue-valence blocks. Consistent with the response time data, there was an interaction between Valence and Action ($F(2, 78) = 10.97$, $p < .001$; $\eta^2_p = .220$), which was moreover accompanied by a significant 3-way interaction with Block type ($F(2, 78) = 12.46$, $p < .001$; $\eta^2_p = .242$). Post-hoc contrasts within target-valence blocks revealed lower error rates in win as compared to loss trials ($t(39) = -3.77$, $p$corr = .002; $d =$

-0.596) and no-incentive trials ($t(39) = -3.00$, $p$corr = .014; $d = -0.474$) when targets had to be approached. Conversely, higher error rates were observed in win trials compared to loss trials ($t(39) = 3.79$, $p$corr = .002; $d = 0.600$) and no-incentive trials ($t(39) = 3.65$, $p$corr = .002; $d = 0.577$) when targets had to be avoided. The remaining post-hoc contrasts in target-valence blocks were not significant (both $p$corr > .2). The same contrasts within cue-valence blocks were not significant (all $p$corr > .1).

Interim summary

We again observed valence-action biases in terms of accuracy, which were more pronounced when valence and action were signaled by the target – which is more consistent with Experiment 2 than Experiment 1 (see across-experiment analysis for further qualification). Since this experiment contrasts concurrent valence and action signals at the moment of the target directly with concurrent signals at the moment of the cue, the results suggest that mere temporal coincidence may not be the main reason for pronounced biases. Instead, it seems that the association with different trial events (cue vs. target) is the defining factor. The differential effects of win versus loss incentives depending on action and block type in Experiment 3 are illustrated in the Supplement Material (Figure S1, Exp 3).

Experiment 3

Figure 5: Response times **(A)** and error rates **(B)** corresponding to cue-valence blocks *(left)* and target-valence blocks *(right)* for the different types of Valence (win/no-incentive/loss) and Action (approach/avoid) in Experiment 3. Although the cue manipulation in this experiment differs from the one applied in Experiment 1 and 2, we here refer to the different block types as cue-valence blocks and target-valence blocks for simplicity. Note that for better visibility of the within-block effects and due to the strong main effect of Block Type, the y-axis for cue-valence blocks is different from that of the target-valence blocks (indicated by #). *Error bars* indicate ± one within-subject standard error.

Across-experiment analysis

In order to investigate the strength of the interaction patterns in response time and error rate data, and to verify potential systematic influences of experimental version, we combined the data of all participants in one rANOVA with 'Experiment' as between-subject factor (N = 134). For this combined analysis, we again focused on the interactions corresponding to the main research questions (Valence × Action and Valence × Action × Block type) and their potential modulation by experimental version. Additional main effects and interactions, as well as relevant post-hoc contrasts, are reported in the Supplement Material (Table S4). As noted above, we will refer to the different block types as cue-valence and target-valence blocks in all experiments although the cue-block manipulation is slightly different in Experiment 3.

Response times

Mean response times collapsed across Experiments 1, 2 and 3 are depicted in **Figure 6A**. Across three experiments, we observed a significant interaction between Valence and Action ($F(1.86, 243.38) = 25.33$, $p < .001$; $\eta^2_p = .162$), regardless of experimental version (Valence × Action × Experiment: $p > .2$). Although this is in line with our predictions, we will not further characterize this interaction given the presence of a higher order

interaction, i.e., Valence × Action × Block type ($F(1.72, 225.13) = 4.51$, $p = .016$; $\eta^2_p = .033$), which was again independent of experimental version (Valence × Action × Block type × Experiment: $p > .7$). When breaking down this interaction, we observed that target-valence blocks featured strong valence-action biases, while cue-valence blocks mostly featured global response acceleration for both win and loss incentives. Specifically, post-hoc contrasts within target-valence blocks showed faster responses in win as compared to loss trials ($t(131) = -4.59$; $p$corr $< .001$; $d = -0.396$) and no-incentive trials ($t(131) = -8.40$; $p$corr $< .001$; $d = -0.726$) when targets had to be approached. In contrast, responses were slower in win compared to loss trials ($t(131) = 2.46$, $p$corr $= .046$; $d = 0.212$) when targets had to be avoided. The remaining contrasts within target-valence blocks were not significant (all $p$corr $> .1$). This pattern is in line with valence-action biases with response speeding and slowing for compatible as compared to incompatible mappings, respectively, again in line with our hypothesis. The analogous analysis in the approach trials of the cue-valence blocks revealed faster responses in both win compared to no-incentive trials ($t(131) = -11.21$, $p$corr $< .001$; $d = -0.968$) and loss as compared to no-incentive trials ($t(131) = -7.68$, $p$corr $< .001$; $d = -0.664$). Moreover, responses in win trials were overall faster than loss trials ($t(131) = -5.16$, $p$corr $< .001$;
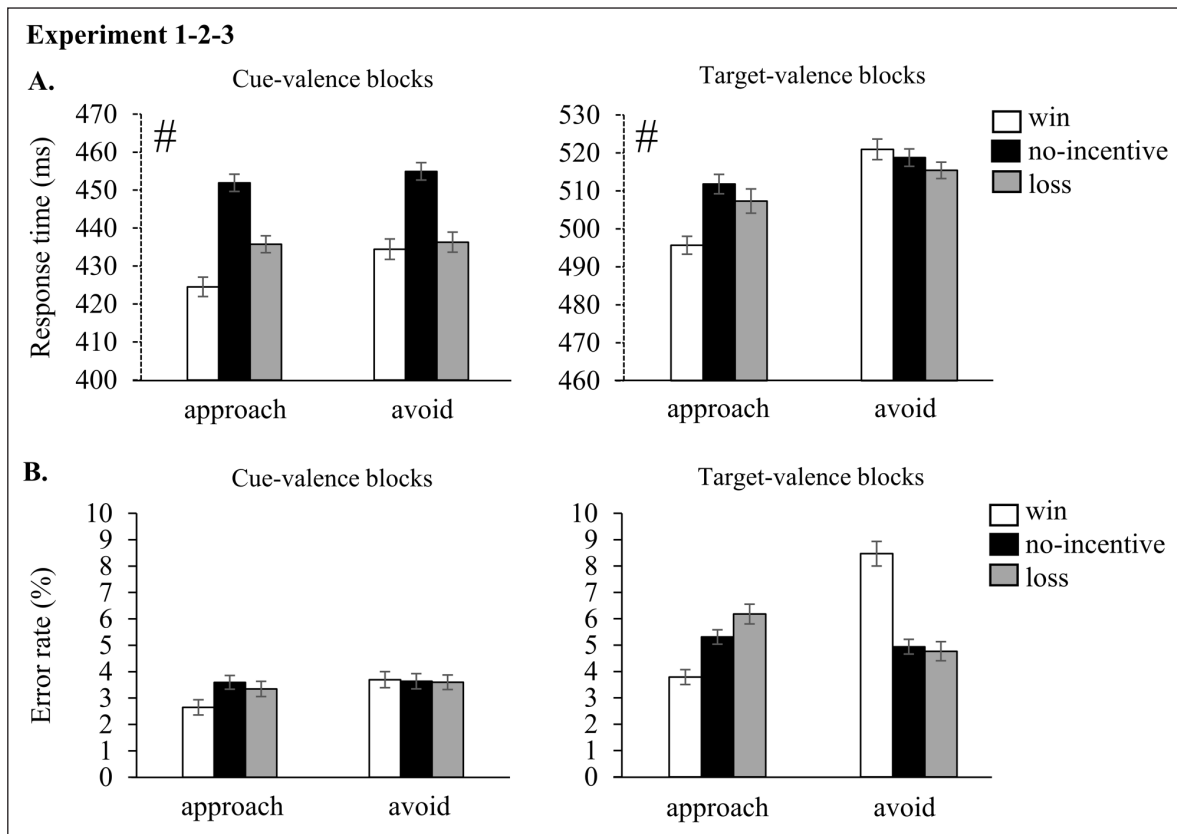
Figure 6: Response times **(A)** and error rates **(B)** corresponding to cue-valence blocks *(left)* and target-valence blocks *(right)* for the different types of Valence (win/no-incentive/loss) and Action (approach/avoid) collapsed over Experiment 1, 2 and 3. Although the cue manipulation differs between experiments, we here refer to the different block types as cue-valence blocks and target-valence blocks. Note that (similar to Figure 5) the y-axis for cue-valence blocks is different from that of the target-valence blocks (indicated by #). The means per condition represent estimated marginal means to account for differences in amount of included participants between experiments. *Error bars* indicate ± one within-subject standard error.

$d = -0.446$). In the avoid condition, the pattern was similar with faster responses for both win compared to no-incentive trials ($t(131) = -9.18$, $p$corr $< .001$; $d = -0.793$) and loss compared to no-incentive trials ($t(131) = -9.04$; $p$corr $< .001$; $d = -0.781$), with no difference between win trials and loss trials ($p$corr > 1). Hence, in contrast to target-valence, the cue-valence manipulation led to global facilitation in both incentive trial types, more or less independent of actual valence and action type.

Error rates

Mean error rates collapsed across Experiments 1, 2 and 3 are depicted in **Figure 6B**. Like in the response time data, we observed a significant interaction between Valence and Action ($F(1.89, 247.97) = 32.67$, $p < .001$; $\eta^2_p = .200$), with no modulation based on experimental version (Valence × Action × Experiment: $p > .5$). Again, this was accompanied by a significant 3-way interaction with Block type ($F(1.62, 211.66) = 16.83$, $p < .001$; $\eta^2_p = .114$), which was independent of experimental version (Valence × Action × Block type × Experiment: $p > .2$). Breaking down the interaction by means of post-hoc contrasts showed that within target-valence blocks, error rates were lower in win compared to loss trials ($t(131) = -4.53$, $p$corr $< .001$; $d = -0.392$) and no-incentive trials ($t(131) =$

-4.32, $p$corr $< .001$; $d = -0.373$) when targets had to be approached. In contrast, higher error rates were observed in win compared to loss trials ($t(131) = 6.52$, $p$corr $< .001$; $d = 0.563$) and no-incentive trials ($t(131) = 6.58$, $p$corr $< .001$; $d = 0.568$) when targets had to be avoided. The remaining contrasts within target-valence blocks were not significant (all $p$corr $> .1$). Within cue-valence blocks, only one post-hoc contrast was significant, indexing lower error rates for win compared to no-incentive trials ($t(131) = -2.68$, $p$corr $= .025$; $d = -0.232$) when targets had to be approached (all other $p$corr $> .1$), suggesting that the cue-valence manipulation had little effect on performance in terms of response accuracy across experiments.

Interim summary

Across three experiments, we found that valence-action biases are more pronounced when valence and action information are concurrently signaled by the target. When valence (and action) was, however, signaled by advance cues, we observed global performance benefits of both win and loss incentives, regardless of valence and action type. The differential effects of win versus loss incentives depending on action and block type across experiments are illustrated in the Supplement Material (Figure S1, Exp 1-2-3). Although each individual experiment featured

this interaction pattern mostly in one of the dependent measures, it was significant in both response times and error rates in the more powerful analysis across experiments, and, in turn, independent of experimental version.

Discussion

The aim of the present work was to examine interactions between incentive valence and action requirements in a paradigm that bridges between existing studies in the motivational and emotional domain. To this end, we employed a novel incentive approach-avoidance paradigm that includes a combination of design features implemented in different previous studies, including changing valence-action combinations from trial-to-trial, no-incentive trials as a neutral baseline, and more natural approach/avoidance movements. In line with our first hypothesis (research question 1), we observed incentive valence-action biases, with performance benefits for compatible mappings (win-approach; loss-avoid) as compared to incompatible mappings (loss-approach; win-avoid) across three experiments. This pattern generally mirrors valence-action biases that have been described in the emotional domain (e.g., Chen & Bargh, 1999; Krieglmeyer et al., 2010; Markman & Brendl, 2005; Seibt et al., 2008), and is moreover consistent with more recent studies employing incentive Go/NoGo paradigms (e.g., Cavanagh, Eisenberg, Guitart-Masip, Huys, & Frank, 2013; Guitart-Masip et al., 2011, 2012; Richter et al., 2014). Although we did not formally test the influence of the combination of different design features (approach/avoid movements, contrasting positive, negative, and no-incentive trials, changing valence-action feature combinations), our data hints at possible reasons why other studies have failed to find such clear interactions (e.g., Hoofs et al., 2019; Verbruggen & McLaren, 2016). Importantly, despite paradigmatic differences at multiple levels, one important common feature of studies that revealed incentive valence-action biases seems to be that positive, negative, and no-incentive stimulus features were intermixed in a trial-by-trial fashion – which is in contrast to block or between-subject manipulations in earlier work. Globally, it seems reasonable to assume that trial-by-trial manipulations (e.g., Krebs, Boehler, & Woldorff, 2010; Novak & Foti, 2015; Zhang, Li, Wang, Liu, & Zheng, 2017) promote transient effects which can induce both performance benefits and costs (i.e., biases), while block or group manipulations (e.g., Locke & Braver, 2008; Umemoto & Holroyd, 2015) emphasize sustained attentional effects that are typically associated with performance benefits (Krebs & Woldorff, 2017). Overall, considering previous inconsistent findings in this domain, it is promising that the general pattern of incentive-based valence-action biases is replicated across different variants of the same task (with a total sample of 134 participants).

By associating valence and action information to either cue or target features in different blocks within the same task, the present paradigm allowed to test additional predictions with regard to different control processes and their contribution to valence-action biases (research question 2). This is inspired by the observation that the majority of studies in the motivational domain use cuing procedures, that are known to trigger preparatory control mechanisms (Braver et al., 2014; Krebs & Woldorff, 2017), while studies on emotional valence-action biases mostly feature valence targets, thereby probing more immediate (and potentially even automatic) effects (Bargh et al., 1996; Chen & Bargh, 1999; Kozlik et al., 2015). We hypothesized that valence-action biases would be pronounced in trials in which valence and action signals are directly associated with targets as compared to cues, considering that there is less room for controlled, preparatory mechanisms (Chiew & Braver, 2016), and in turn a higher probability of (automatic) response activation (Krebs & Woldorff, 2017; Ridderinkhof, Forstmann, Wylie, Burle, & van den Wildenberg, 2011). Support for this notion also comes from transcranial magnetic stimulation studies showing that positive and negative events differentially bias motor excitability that probes the onset of corresponding approach and avoid responses (Cai, Oldenkamp, & Aron, 2011; Chiu, Cools, & Aron, 2014; Swann et al., 2012). In line with our prediction, we found that valence-action biases were pronounced when valence and action were signaled by the target as compared to the cue, as indexed by a 3-way interaction between Valence, Action, and Block type in the response time data (Experiment 1). In two follow-up experiments, we explored potential alternative explanations for this result pattern. In Experiment 2, we tested if the difference between target-valence and cue-valence blocks would be diminished or even abolished by introducing a delay between the target and the feedback event, based on the idea that immediate valence feedback might have increased the impact of target-valence relative to cue-valence, e.g., through associative learning. This manipulation again revealed pronounced valence-action biases in the target-valence blocks, indicating that immediate feedback is at least not a major driving factor for this effect. Of note, the respective result pattern was now expressed in the error rate data rather than in terms of response speed (see below). Experiment 3 was conducted to explore whether the differential effects between block types could be driven by mere temporal coincidence of valence and action signals – which is unique to target-valence blocks in Experiments 1 and 2. To this end, valence and action signals were now also concurrently presented in the cue-valence blocks. If mere temporal coincidence would amplify valence-action biases, there should be no systematic difference between block types in this setup. However, we again found pronounced biases in the target-valence as compared to the cue-valence blocks in the error rate data, suggesting that these differences are driven by the association with different trials events, i.e., cues and targets.

In order to test for systematic differences between experimental versions regarding the expression of this interaction in response time and error rate data, we combined the data of all 134 participants and included experiment as between-subject factor. This analysis confirmed that positive and negative incentive valence led to a differential facilitation of approach and avoid responses when valence and action were signaled by

the target. In contrast, if this information was signaled by cues ahead of time, it triggered global response facilitation more or less regardless of actual valence and action requirements. Importantly, this pattern was present in both response time and error rate data and did not differ significantly between experiments, indicating that variations in the result patterns (including response time vs. error rate data) are non-systematic. We interpret the results in the light of different control mechanisms (preparatory versus immediate) that are triggered by the different trial events. Specifically, target-locked incentives induce performance benefits and costs when valence and action information is compatible and incompatible, respectively, which likely arises due to a fairly automatic response activation dependent on positive and negative valence stimuli. In contrast, cue-locked incentives result in performance benefits, more or less independent of actual valence and action type, suggesting that preparatory processes are emphasized that can counteract potential inherent valence-action biases. This dissociation between block types is especially interesting considering that the task goal is identical in all trials, i.e., fast and correct performance to maximize incentives. It seems that inherent valence-action biases could not be overridden by the top-down task goal if there is no time for strategic preparation. Although the bias was mainly expressed in response times in Experiment 1 and in accuracy in Experiments 2 and 3, the across-experiment analysis provided no evidence for a systematic effect of experimental version in that the interaction of interest was present in both dependent measures and in the absence of a higher-order interaction with experiment.

The current results further illuminate the nature of valence-action biases in that they bridge between previous studies in different domains. Specifically, by linking valence and action signals to either targets or cues, we were able to relate the results to studies in the emotional domain, which first reported response biases to valenced target stimuli (e.g., Chen & Bargh, 1999; Krieglmeyer et al., 2010; Markman & Brendl, 2005; Seibt et al., 2008), as well as in the motivational domain, which mostly employed cueing designs (e.g., Geurts, Huys, Den Ouden, & Cools, 2013; Guitart-Masip et al., 2011, 2012; Hoofs et al., 2019; Wagenbreth et al., 2015). Moreover, the present study extends previous work in that it dissociates processes related to automatic evaluation and immediate response activation (target-locked), and more controlled influences related to preparatory attention (cue-locked). Specifically, the target-locked effects are not only in line with previous findings in the emotional domain (as discussed above), but also with the observation that reward-related stimuli can impair performance if they occur in an irrelevant spatial location or are linked to a competing response (Anderson, Laurent, Yantis, Grados, & Umaña, 2011; Anderson, Laurent, & Yantis, 2011; Krebs, Boehler, Egner, & Woldorff, 2011; Krebs et al., 2010). Interestingly, while most previous studies reporting valence-action biases in the motivational domain used learning or conditioning procedures (Freeman et al., 2014; Geurts et al., 2013; Guitart-Masip et al., 2011, 2012; Huys et al., 2011), we

observed that these biases can also be brought about by instructing certain stimulus-valence mappings without excessive training.

With regard to the cue-locked effects, we also replicate well-known facilitation effects that rely on controlled, preparatory attention mechanisms (Braver et al., 2014; Krebs & Woldorff, 2017; Pessoa & Engelmann, 2010). Interestingly, these effects of incentive cue (or block) manipulations seem to be largely independent of the specific task requirements; and the current study furthermore suggests that they are even independent of inherent response tendencies (in contrast to the target-locked effects). And related to this, the present results are also in line with our earlier study (Hoofs et al., 2019), in which we manipulated incentive valence in a cued approach/avoidance task in a between-subject design (group 1: win vs. no-incentive; group 2: loss vs. no-incentive). Despite the differences in design, we observed global behavioral facilitation for both types of valence, regardless of the required action, which is similar to the present study. That said, the global facilitation after incentive cues seems to be inconsistent with the studies by Guitart-Masip and colleagues (2011, 2012), which featured concurrent valence and action signals at the moment of the cue (similar to our manipulation in Experiment 3). In contrast to our own findings, these studies revealed cue-induced valence-action biases in the expected direction. However, this discrepancy may be explained by additional important differences in the design, including Go/NoGo vs. approach/avoid actions, the absence vs. presence of no-incentive trials, fixed vs. variable valence-action combinations, and learned vs. instructed feature-reward associations. First, in the approach/avoidance paradigm, withholding a response was never beneficial, which is in contrast to a Go/NoGo design. In turn, participants would have to prepare a response in every trial in the present design, ameliorating basic differences between cued Go and NoGo trials (see Schevernels et al., 2016). Second the introduction of no-incentive trials might have modulated the perceived value of potential wins and losses. In our earlier study, we compared the impact of win and loss trials relative to their respective no-incentive baseline in independent samples and found that they had a similar impact on performance (Hoofs et al., 2019; see also Verbruggen & McLaren, 2016). This is in contrast to the present study (and Guitart-Masip et al., 2011) and suggests that the trial context may modulate how positive and negative incentives are processed. Third, we believe that the fixed mapping between valence and action information in the studies by Guitart-Masip and colleagues renders their task easier – above and beyond the fact that there are fewer conditions in total (no no-incentive stimuli and no target-valence blocks). Specifically, once they have learned the contingencies, participants could in principle perform the task by attending to two only fractal stimuli (again assuming that NoGo cues did not require any preparation or action; (see Schevernels et al., 2016). Given that the current study is more cognitively involving, it is all the more interesting that participants are still prone to commit errors in trials containing incompatible valence-action information – which supports the notion of some

level of automaticity. Finally, we note that the mappings in the paradigm by Guitart-Masip and colleagues had to be learned (which is cognitively demanding at a different level), while the feature associations in the current study were explicitly instructed. Together, it seems possible that the combination of the discussed paradigmatic differences (and especially the response mode and the number of conditions) contributed to the observation of cue-triggered valence-action biases reported by Guitart-Masip and colleagues (2011) that were absent in our study. That said, testing the specific contribution of these different design aspects is beyond the scope of the present study, and our interpretations therefore remain speculative. Regardless, we believe that the present design allows to compare cue-locked and target-locked effects of valence/action mappings in a fairly controlled manner. This, however, does not imply that valence-action biases *cannot* be triggered by cues in a different task context.

To conclude, across three experiments, we observed performance benefits for compatible valence-action targets versus incompatible ones (win-approach; loss-avoid vs. win-avoid; loss-approach), consistent with the idea that positive and negative incentive stimuli trigger opposing response tendencies – similar to inherently emotional events. In contrast, when valence and action information were bound to cues, both positive and negative incentive stimuli led to response facilitation regardless of the actual response, which is reminiscent of well-known preparatory effects of incentive cues across diverse cognitive tasks and functions. While these findings help to bridge between the motivational and emotional domain with regard to (inherent) valence-action biases, future studies are needed for a more direct comparison. Finally, taking a broader perspective, we believe that the present results may be valuable for applied domains, such as behavioral approach/avoidance training (Adams, Lawrence, Verbruggen, & Chambers, 2017; Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017). Specifically we think that the current study may help to optimize these procedures in terms of event timing, as well as in terms of the potential use of monetary incentives for establishing novel stimulus-response mappings.

Data Accessibility Statement
De-identified data, study materials, and statistical output will be made available after manuscript publication via this Open Science Framework page: https://osf.io/69g3y/.

Additional File
The additional file for this article can be found as follows:

- **Supplement Material.** The Supplement Materials include detailed overviews of the statistical tests of interest for each individual experiment (Tables S1–S3), statistical tests across experiments 1-2-3 (Table S4), and a figure illustrating the differential effects of win versus loss incentives depending on action and block type for each experiment as well as across experiments (Figure S1). DOI: https://doi.org/10.1525/collabra.205.s1

Author Contributions
Vincent Hoofs contributed to the development of the study, collected and analyzed the data, and contributed to the writing of the manuscript. Ruth M. Krebs contributed to study design and writing of the manuscript. C. Nico Boehler contributed to the writing of the manuscript.

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