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Reward functioning from an attentional perspective and obsessive-compulsive symptoms—an eye-tracking study

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Original Research

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Abstract

Background. Recently, a novel approach to obsessive-compulsive disorder has emerged, implicating altered reward functioning in the disorder. Yet, no study to date has directly examined the attentional aspect of reward functioning in participants with obsessive-compulsive (OC) symptoms, with past research mostly relying on reaction-time-based tasks.
Methods. A reward-based value-modulated attentional capture task was completed by a sample of nonclinical student participants—44 with high (HOC) and 48 with low (LOC) levels of OC symptoms. We measured the extent to which high and low reward-signaling distractors captured attention and impaired performance on the task, resulting in a lower possibility of obtaining a monetary reward. Attentional capture was indexed via fixation data, and further explored using saccade data.
Results. Both groups performed more poorly when a high-reward signaling distractor was present, compared to when a low-reward signaling distractor was present. Importantly, this difference was significantly greater in the HOC group, and was found to be driven by the specific effects of reward-signaling distractors. Similar results emerged when exploring saccade data, and remained significant after controlling for both addiction-related compulsivity and depressive symptoms.
Conclusions. Current findings suggest that attentional reward-related functioning may be associated with OC symptoms. Different aspects of reward functioning, including attention, should be further explored and incorporated into future research and clinical endeavors.

Introduction

Obsessive-compulsive disorder (OCD) is a chronic and debilitating disorder with a lifetime prevalence ranging between 2% and 3%.[1] It is characterized by two main phenomena: *obsessions*, defined as recurrent, distressing, and intrusive thoughts or images, and/or *compulsions*, repetitive behaviors, or mental acts, performed in order to reduce obsession-related aversive emotions and anxiety. Accordingly to the traditional view of the disorder, the stereotypical portrait of an obsessive-compulsive (OC) individual is usually of an excessively self-controlled, risk-aversive person that acts in order to avoid potential loss or harm.[2]

Although this traditional description fits well with studies showing increased harm avoidance in OCD,[3-6] more recent research has challenged this perspective, yielding results that conflict with the stereotypical portrait of OCD in three important domains: impulsivity, decision-making, and reward functioning.[7-12] First, research shows patients with OCD to display increased impulsivity,[7,8,11,13] specifically highlighting cognitive and attentional impulsiveness in the disorder.[12,14] Second, impaired decision-making was found to characterize individuals with OCD, with both neurocognitive and clinical studies reporting risky decision-making in patients with OCD, compared with healthy non-OCD participants, namely, preference for an immediate reward despite negative future consequences.[11,12,15] Finally, recent research has also shown alterations in reward functioning in OCD, including, among others, reward anticipation (eg,[10,16]; for a review see[9]), reward valuation (eg, [17]), reward generalization (eg,[18]), and most relevant for this study—reward-based learning (eg,[19,20]).

A major aspect that has been mostly overlooked by most research in the field of reward-based learning in OCD is that of attention. However, learning from an attentional perspective is an integral part of reward processing.[21] Moreover, as attention precedes behavior and guides higher thought processes, (working) memory, decision-making, and other higher order cognitive processes,[22,23] it seems vital to better understand it, also in OCD. Theoretically, reward learning from an attentional perspective, termed reward-based *Selection History*, refers to the effects of prior reward-learning on subsequent attention allocation, or, put differently, to the way in which one's learning of a (rewarding) value of specific stimuli affects the way attention is later allocated to those stimuli, compared to non or less-rewarded ones.[24] Research on reward-based selection

history in healthy individuals has consistently shown that stimuli which gained a rewarding value can later guide visuospatial attention, even without conscious awareness.[25,26] Thus, exploring alterations in reward-based selection history in OCD may potentially shed much-needed light on mechanisms related to reward functioning in the disorder.

One well-established experimental paradigm used to examine the attentional manifestation of reward learning is the value-modulated attentional capture task (the VMAC task[27]) designed to assess the attentional manifestation of Sign-tracking—the process by which *reward-predictive* cues gain precedence in directing the organism's behavior.[28,29] Briefly, the VMAC task is a visual-search task, in which participants are presented with a search display, comprised of six shapes arranged evenly around an imaginary circle—five circles (ie, nontarget shapes) and one diamond (ie, the target shape). Within each of the five circles appears a line tilted 45° to the left or right, while within the diamond a line-oriented horizontally or vertically appears. Participants need to report the orientation of the line within the diamond as quickly as possible by pressing a corresponding key. Importantly, one of the nontarget stimuli in each display signals the magnitude of the reward to be won (high versus low reward) on the trial. However, actual reward delivery is not contingent on these reward-signaling stimuli, but rather on correctly responding to the target. Moreover, any attentional capture by reward-signaling distractors impedes performance (slowing it down, increasing erroneous responses), thereby lowering the possibility of obtaining the reward. The VMAC task consistently shows reduced task performance when high-reward signaling cues are present, compared with when low-reward signaling cues are shown, presumably due to the former capturing participants' attention to a higher extent, thereby inhibiting the search for the target.[27,30,31]

Most relevant to this study, recent studies using the VMAC task have reported a positive correlation between performance on the task and compulsivity, such that participants with higher compulsivity scores also show greater attentional capture by reward-signaling stimuli, even at the expense of procuring the reward itself.[32-34] While considerably advancing the knowledge in the field, this study elaborates on these previous studies in two important ways. First, prior studies used a reaction-time (RT)-based version of the task, and thus could not provide additional information as to the course of attention deployment before the moment of measurement.[35,36] For example, when responses are slow or incorrect, one cannot know the actual deployment of attention that led to this deficient performance—was attention captured by the reward signaling cue itself? was attention deployed to any of the nontarget shapes? Second, previous studies were correlative studies based on convenience samples, with no relevant inclusion/exclusion criteria implemented in a group-comparison design.

Aiming to elaborate on previous findings in the field, this study compared participants with high (HOC) and low (LOC) levels of OC symptoms as they completed an eye-tracking-based version of the VMAC task. On the basis of the above-described previous studies, we expected the HOC group to show a greater reward-related attentional capture as compared with the LOC group.

Method

Participants

Six hundred and sixty-seven undergraduate students were screened using the Obsessive-Compulsive Inventory-Revised (OCI-R[37]). Those scoring at the top of the OCI-R distribution comprised the HOC group, contingent on having an OCI-R score > 27, a score that is well above the clinical cutoff score on this scale (OCI-R = 21[37]), denoting severe OCD.[38] This enabled the enrollment of participants that most closely resemble the clinical population of interest. Importantly, only those scoring above 21 also on the day of their participation, held several weeks following the initial screening, were enrolled in the study. The LOC group consisted of those who scored at the bottom of the sampling pool, contingent on having an OCI-R score < 10 (as 15 is considered the cutoff score reflecting minimal OC symptoms[38]). The final sample included 92 participants: Forty-four HOC participants (M_{age} = 23.22 years, SD = 1.62, range = 20–28 years; 34 women), and 48 LOC participants (M_{age} = 23.50 years, SD = 1.98, range = 20–31 years; 32 women). The study protocol was approved by the Research Ethics Council of Tel Aviv University. We only invited participants with normal or corrected-to normal vision, excluding usage of multi-focal eyewear to prevent eye-tracking calibration difficulties. All participants provided informed consent and received course credit for participation.

1.1. Measures

Obsessive-compulsive symptoms

OC symptoms were measured using the OCI-R,[37] an 18-item self-report questionnaire assessing OC symptoms. Participants indicate their level of distress associated with each symptom on a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*very much*), resulting in a 0-to-72 total score. The OCI-R has been shown to have good validity, test-retest reliability, and internal consistency in both clinical,[37,39,40] and nonclinical samples.[41,42] Internal consistency in this study was 0.95.

Depression and anxiety symptoms

Depression and anxiety symptoms were measured using the depression and anxiety subscales of the Depression, Anxiety, and Stress Scales-21 (DASS-21[43])—a 21-item self-report questionnaire assessing dimensional components of depression and anxiety. Each individual item is rated on a 4-point scale ranging from 0 (*the item does not apply to me at all*) to 3 (*the item applies to me very much or most of the time*), on which participants indicate how much each statement applied to him/her experience over the past week. The DASS-21 has been shown to have high reliability, validity, and internal consistency in both clinical and nonclinical groups.[43-45] Internal consistency in this study was 0.92 and 0.86, for the depression and anxiety subscales, respectively.

Compulsivity-associated problems

Compulsivity-associated problems were measured using the recently developed Brief Assessment Tool for Compulsivity-Associated Problems (BATCAP[33]). The BATCAP is a two-part questionnaire. In the first part, participants indicate whether they endorse any of a set of compulsivity-associated behaviors (ie, checking, washing, ordering, binge eating, alcohol use, gambling, and excessive internet use), as it pertains to the previous month. For each endorsed behavior, participants are then required to complete the second part of the BATCAP, comprised of six items measuring the severity of the compulsivity-related problem. Each item is rated on a 5-point scale, ranging from 0 (*none/not at all*) to 4 (*extreme/constant*), for a 0-to-24 total score. The BATCAP provides two sub-scores—one for OCD compulsivity-associated problems (ie, accumulative score of checking, washing, and ordering),

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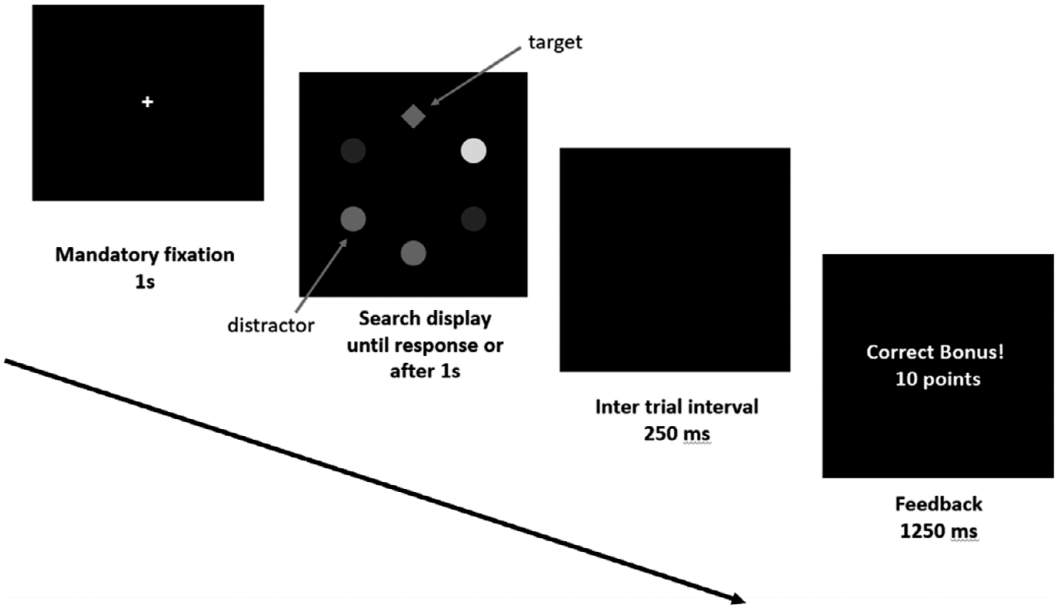

Figure 1. Trial sequence of the value-modulated attentional capture (VMAC) task. Each trial of the task began with a centrally located fixation-cross mandating a 1-s fixation for the search display to appear. The search display was then presented until a fixation ≥100 ms was registered within any of the six presented shapes, or after 1000 ms have elapsed. Next, the display blanked for 250 ms, followed by the feedback display, presented for 1250 ms. Participants were asked to locate the target "as accurately and quickly as possible" and then to fixate on it. One of the nontarget shapes (ie, the distractor) signaled the magnitude of the reward that could be earned, if participants fixated the target fast enough (ie, before 1000 ms elapsed). Depending on the color of this distractor (red or blue), participants received either a high or a low reward. Fixating on any of the four non-distractor shapes was considered an "error" response and no reward was delivered.

and one for addiction compulsivity-associated problems (ie, binge eating, alcohol use, gambling, and excessive internet use). The two BATCAP subscales were found to be moderately to highly correlated with well-established measures of the corresponding disorders (ie, the Alcohol-Use Disorders Identification Test[46] and the OCI-R[33,37]). Internal consistency in this study was 0.91 and 0.96 for the BATCAP-addiction and BATCAP-OCD sub-scores, respectively.

1.2. The VMAC task

The current task was based on the additional singleton paradigm,[47,48] incorporating elements from the version used by Albertella et al.[33] when exploring the VMAC performance-compulsivity association. It was designed and executed using the Experiment Builder software (version 2.1.140; SR Research Ltd., Mississauga, Ontario, Canada).

Each trial comprised a search display (see Figure 1) consisting of six differently colored shapes, 310pxl in diameter—one diamond serving as the to-be-found *target* and five circles (ie, nontarget stimuli). Of the five nontarget circles, one was always colored in either red or blue, serving as the reward-signaling shape (ie, *the distractor*). Specifically, one of these two colors signaled a high-reward trial, while the other signaled a low-reward trial, with distractor color counterbalanced across participants. The colors of the other five shapes in each display (the diamond and the remaining four circles) were randomly sampled from a fixed set of colors without replacement (green, yellow, pink, brown, and cyan; see[47]). The six shapes were presented at equal distances from the center of an imaginary circle (102pxl diameter) on a black background. Shape location was randomly determined per trial.

Each trial began with a centrally located fixation-cross mandating a 1-s fixation for the search display to appear, verifying that each trial began only when participants' gaze was located at the screen's center. The search display was then presented until a response was registered by the eye tracker or after 1000 ms elapsed with no response. A *Response* was defined as a fixation ≥100 ms made either on the target (ie, the diamond) or on any of the five circles—the reward-signaling distractor (ie, the red or blue circle) and the four nontarget shapes (the remaining colored circles). Next, the display blanked for 250 ms, followed by a 1250 ms feedback display. Participants were asked to locate the target "as accurately and quickly as possible" and fixate on it. See Figure 1 for an illustration of a single trial.

To gauge the location of each response, six areas of interest (AOIs), each with a diameter of 142pxl, were defined, one per shape. A response was deemed *Correct* when participants fixated on the target AOI. Correct responses on low-reward trials (ie, trials containing the distractor signaling low-reward) resulted in a "correct-1 point" feedback slide. Correct responses on high-reward trials (ie, trials containing the distractor signaling high-reward) resulted in "correct-10 points bonus trial!" slide. To encourage quick responses, a latency limit of 650 ms was set for correct responses. When correct responses were above this limit a feedback slide of "correct but too slow" appeared. These responses were still considered correct as participants located the target with no prior fixations on nontarget shapes. Conversely, a response was considered an *Error* if a fixation was registered within any of the five nontarget AOIs. This terminated the trial, omitting the possibility to obtain the reward, and resulting in an "error-0 points" feedback slide. Finally, as stated above, if no fixation was registered within any of the six AOIs before 1000 ms elapsed, a feedback slide reading "Too slow: please try to respond faster" was shown.

Participants first performed a no-reward 72-trial baseline block to get acquainted with the task and train on performing it. Here, the red and blue colored circles had no reward-signaling value, but rather served as ordinary nontarget shapes. Next, participants completed six 72-trial experimental blocks, as described above, for a total of 432 experimental trials. Before the experimental

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blocks, participants were told that they could now earn points depending on their performance, which would be converted to actual money (no information was given about how many points would be converted to how much money). Participants were also told that the presence of either a red or a blue circle in the display would indicate how many points could be earned (ie, high versus low reward) if they fixated on the target accurately and quickly enough, with no additional information. Half of the trials in each block featured the red distractor, and half the blue.

Before each block, a 5-point eye-tracking calibration followed by a 5-point validation procedure was performed. The block did not ensue unless a visual deviation <0.5° was achieved for each point on both the *X*- and *Y*-axes. A 2-minute break was given between blocks to reduce fatigue.

Eye-tracking apparatus

Eye-tracking data were collected and recorded using the remote head-free high-speed EyeLink Portable-Duo apparatus and the Experiment Builder software (SR-research, Ottawa, Ontario, Canada). Participants sat approximately 700 mm from the screen. Real-time monocular eye-tracking data were recorded continuously throughout the task at 500 Hz, with a 1920X1080-pixel display resolution. Eye-tracking data were processed using EyeLink Data Viewer software, version 3.1.246 (SR-research, Ottawa, Ontario, Canada). Fixations were defined as at least 100 ms of stable fixation within 1° visual angle.

Eye-tracking-based measures

Number of *overall error responses* was calculated per block, by counting the number of trials on which participants fixated any of the five nontarget AOIs, resulting in no reward. Number of *distractor error responses* was calculated per block, by counting the number of error trials resulting from specifically fixating the reward-signaling distractor. Finally, number of *non-distractor error responses* was calculated per block, by counting the number of error trials resulting from fixating one of the other nontarget shapes (excluding the reward-signaling distractor).

1.3. Procedure

Participants were tested individually in a quiet room at the university. They were seated in front of the eye-tracking monitor and were given the task instructions as described above. They were also informed that before the appearance of each display a fixation cross will appear at the screen's center, on which they should fixate to make the display itself appear. Following the task participants filled out the self-report questionnaires. Then they were then thanked for participation, debriefed, and paid the monetary amount "won" during the task.

1.4. Data analysis

A sample of 82 has a power of 90% to detect a Group-by-Reward interaction at an alpha level of .05, of an effect size similar to that reported in previous studies using a similar version of the VMAC task ($\eta^2_p = 0.12$[49]). Hence, 41 participants per group was determined as the minimum sample size. Power analysis was performed using G*Power 3.1.9.4[50].

Independent sample *t*-tests compared between groups on age, OCI-R, DASS-21, and BATCAP scores, and a chi-square test compared groups on gender ratio.

We examined group differences in number of *overall error responses*, using a 2×6×2 mixed-model analysis of variance (ANOVA) with groups (HOC and LOC) as a between-subjects factor, and block (1–6) and reward (high, low) as within-subject factors. To further elucidate group differences on overall error responses and examine the specific effects of the reward-signaling distractors on task performance, we also compared groups on number of *distractor-error responses*, and number of *non-distractor error responses.* For significant findings, we performed an analysis of covariance (ANCOVA) entering both depression and BATCAP-addiction scores as covariates to the above-described main analyses. BATCAP-addiction scores were added to verify that emergent results are not due to addiction-related compulsivity, which was also found to be related to performance on the VMAC task[33,34]. Follow-up simple effects analyses were conducted using within-groups dependent-samples *t*-tests.

All statistical analyses were conducted using SPSS (IBM, version 27.0) and were two-sided, using an α of 0.05. Effect sizes are reported using η^2_p for ANOVAs and Cohen's *d* for group mean comparisons.

Results

Data are openly available in Open Science Foundation (OSF) at https://osf.io/n7sx5/?view_only=37e0c2d9de2f43cdaa57132ee803d81e

1.5. Demographic and clinical characteristics

Demographic and clinical characteristics of the two groups are described in Table 1. Significant group differences were noted on OCI-R scores, $t(90) = 17.09$, $P < .000$, Cohen's $d = 3.57$, 95% CI [2.90, 4.22]; DASS-21 depression, $t(89) = 5.87$, $P < .000$, Cohen's $d = 1.23$, 95% CI [0.78, 1.68] and anxiety scores, $t(89) = 7.30$, $P < .000$, Cohen's $d = 1.53$, 95% CI [1.06, 1.99]. Groups also differed on BATCAP-OCD $t(89) = 7.96$, $P < .000$, Cohen's $d = 1.67$, 95% CI [1.18, 2.15] and BATCAP-addiction $t(89) = 4.94$, $P < .000$, Cohen's $d = 1.04$, 95% CI [0.59, 1.47]. No group differences were noted for age, $t(90) = .72$, $P = .47$, or gender ratio, $\chi^2(1) = 1.27$, $P = .26$.

Table 1. Demographic and Clinical Characteristics of the Two Groups

	LOC group (n = 48)		HOC group (n = 44)	
Measure	M	SD	M	SD
Age	23.50[a]	1.98	23.22[a]	1.62
Gender ratio (M:W)	16:32[a]	—	10:34[a]	—
OCI-R- total score	8.31[a]	5.63	36.75[b]	9.91
DASS-21				
Depression score	1.14[a]	1.82	6.12[b]	5.54
Anxiety score	0.58[a]	0.89	5.02[b]	4.11
BATCAP				
OCD subscale	1.60[a]	2.93	19.88[b]	15.62
Addiction subscale	3.93[a]	6.58	14.44[b]	12.99

Note. Different superscripts signify differences between groups at $P < .001$.
OCI-R total: $p < .001$; DASS-21_depression: $p < .001$; DASS-21_anxiety: $p < .001$; BATCAP_OCD: $p < .001$; BATCAP_ADDICTION: $p < .001$.
Abbreviations: BATCAP, brief assessment tool for compulsivity associated problems; DASS-21, depression, anxiety and stress scales-21; HOC, high obsessive–compulsive tendencies; LOC, low obsessive–compulsive tendencies; OCI-R, obsessive–compulsive inventory-revised.

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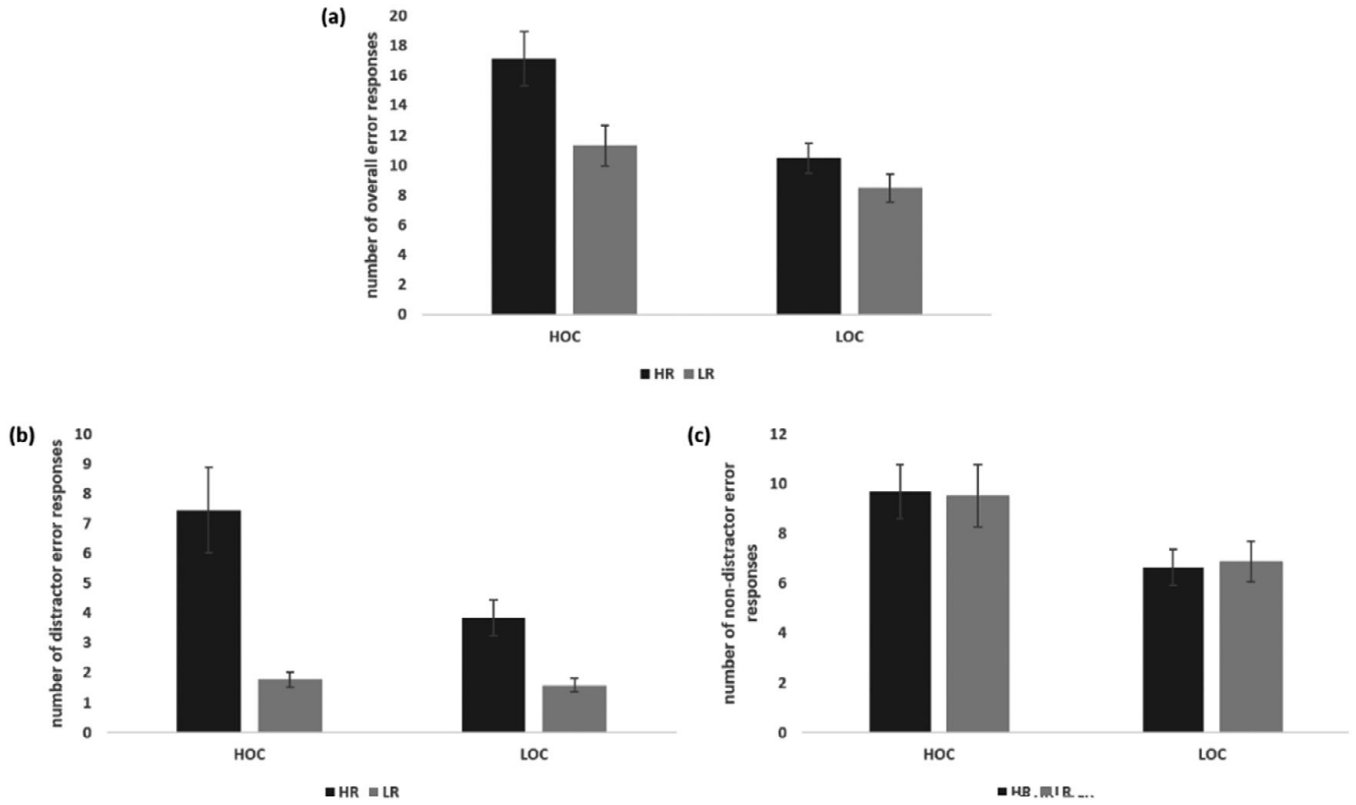

Figure 2. Reward valence by Group (collapsed across blocks) for (a) Number of overall error responses; (b) Number of distractor error responses; (c) Number of non-distractor error responses. HOC, high obsessive-compulsive tendencies; LOC, low obsessive-compulsive tendencies; HR, high reward; LR, low reward.

1.6. Main analysis

Whereas the omnibus Group×Block×Reward interaction for *overall error responses* was not significant, $F(5, 83) = .72$, $P = .61$, a significant Group×Reward interaction emerged $F(1, 87) = 4.90$, $P = .03$, $\eta^2_p = .05$ (Figure 2a), which remained significant following the ANCOVA, $F(1,85) = 4.20$, $P = .04$, $\eta^2_p = .05$. We therefore collapsed across blocks for the remaining analyses. Follow-up simple effects analysis showed that HOC participants fixated the nontarget shapes significantly more on high-reward trials ($M = 17.14$, SD = 11.87) than on low-reward trials ($M = 11.31$, SD = 8.81), $t(41) = 3.64$, $P < .001$, Cohen's $d = 0.56$. LOC participants also fixated the nontarget shapes significantly more on high-reward trials ($M = 10.46$, SD = 6.78), than on low-reward trials ($M = 8.46$, SD = 6.44), $t(46) = 2.52$, $P < .015$, Cohen's $d = 0.37$, but to a lesser extent.

For *distractor error responses*, the omnibus Group×Block×Reward was not significant, $F(5, 83) = 1.06$, $P = .38$. However, here, too, a significant Group×Reward interaction emerged $F(1, 87) = 5.08$, $P = .03$, $\eta^2_p = .06$ (see Figure 2b), which also remained significant following the ANCOVA, $F(1,85) = 5.93$, $P = .02$, $\eta^2_p = .06$. Simple effects analysis showed that HOC participants fixated the high-reward signaling distractor significantly more ($M = 7.45$, SD = 9.27) than the low-reward signaling distractor ($M = 1.78$, SD = 1.68), $t(41) = 3.89$, $P < .000$, Cohen's $d = 0.60$. Although to a lesser extent, LOC participants also fixated on the high-reward signaling distractor significantly more times ($M = 3.83$, SD = 4.11) than the low-reward signaling distractor ($M = 1.59$, SD = 1.52), $t(46) = 3.62$, $P < .001$, Cohen's $d = 0.53$.

For *non-distractor error responses*, the omnibus Group×Block×Reward interaction was nonsignificant, $F(5, 83) = .68$, $P = .64$, as was the Group×Reward interaction, $F(1, 87) = .15$, $P = .70$.

1.7. Exploratory analysis—Saccades data

To better understand the significant Group×Reward interaction for distractor error responses (Figure 2b), we also explored two measures of saccades (ie, rapid eye movements between two spatial locations). First, we examined the *number of saccades ending within the distractor AOI*, which reflects eye movements that ended within the distractor AOI, but that did not necessarily end with a fixation[1]. We then explored *number of saccades ending within/nearest to the distractor AOI*, which takes in to account eye movements that did not necessarily end within the distractor AOI, but closest to it (compared to all other AOIs), signaling an orientation response in the direction of the distractor AOI[2]. For both measures, we used the same analyses as described above for distractor error responses (ie, the Group-by-Reward interaction based on fixation data).

For *number of saccades ending within the distractor AOI*, a significant interaction emerged, $F(1, 87) = 4.22$, $P = .04$, $\eta^2_p = .05$ (Figure 3a), which became even more significant following the ANCOVA analysis, $F(1,85) = 7.81$, $P = .006$, $\eta^2_p = .08$. Simple effects analysis showed that HOC participants made significantly more saccades towards the high-value distractor ($M = 18.40$, SD = 15.31)

[1]This measure includes both saccades that ended with a fixation (and hence were included in the main analysis) and those that did not.

[2]This measure includes both saccades that ended within the distractor AOI (also included in the first saccade analysis) and saccades that ended nearest to the distractor AOI (compared to all other AOIs).

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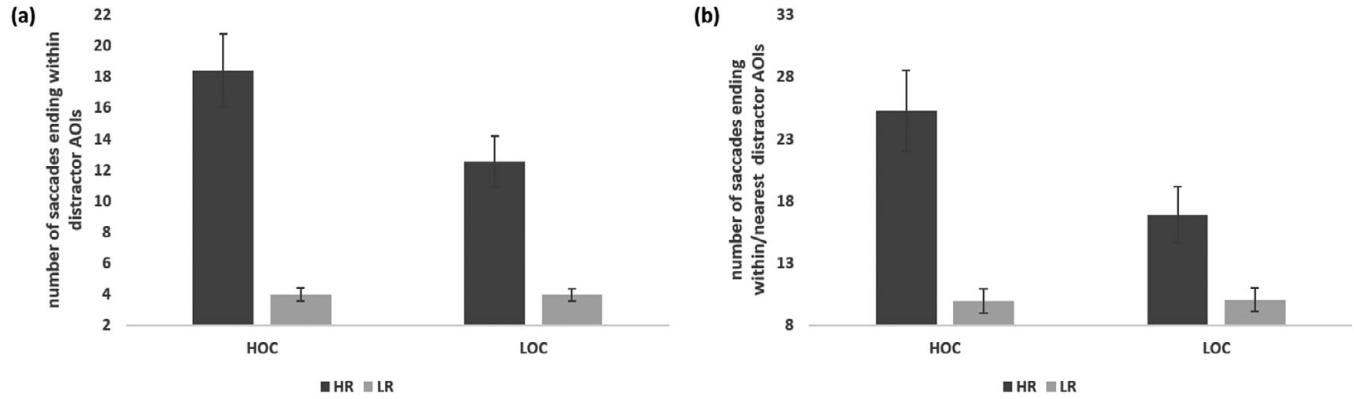

Figure 3. Reward valence by Group for (a) Number of saccades ending within distractor AOIs (ie, reward-value signaling AOIs; high or low); and (b) Number of saccades ending within/nearest distractor AOIs (ie, reward-value signaling AOIs; high or low). HOC, high obsessive-compulsive tendencies; LOC, low obsessive-compulsive tendencies; HR, high reward; LR, low reward.

than towards the low-value distractor (M = 4.00, SD = 2.75), $t(41) = 6.06$, $P < .001$, Cohen's $d = 0.93$, as did LOC participants (high-value distractor; $M = 12.55$, SD = 11.35, low-value distractor; $M = 3.96$, SD = 2.82), $t(46) = 5.29$, $P < .001$, Cohen's $d = 0.77$, but to a lesser extent.

For *number of saccades ending within/nearest to the distractor AOI,* a significant interaction emerged, $F(1, 87) = 4.82$, $P = .03$, $\eta^2_p = .05$ (Figure 3b, which remained significant following the ANCOVA analysis, $F(1,85) = 5.76$, $P = .02$, $\eta^2_p = .06$. Simple effects analysis revealed that HOC participants made significantly more saccades toward the high-value distractor ($M = 25.26$, SD = 21.16) than the low-value distractor ($M = 9.92$, SD = 6.31), $t(41) = 4.75$, $P < .001$, Cohen's $d = 0.73$, and to a higher extent compared to LOC participants (high-value distractor; M = 16.87, SD = 15.54, low-value distractor; M = 10.04, SD = 6.44), $t(46) = 3.03$, $P < .004$, Cohen's $d = 0.44$.

Discussion

Building on recent research in OCD implicating alterations in reward functioning in the disorder,[9,10,12] this study examined reward functioning in OCD from an attentional standpoint. Specifically, participants with high and low levels of OC symptoms completed an eye-tracking-based version of the VMAC task. We measured the extent to which reward-signaling distractors captured participants' attention and impaired their performance, resulting in a lower possibility of obtaining a monetary reward. Results showed that while both groups performed more error responses on trials with a high-reward signaling distractor, compared to trials with a low-reward signaling distractor, this difference was significantly greater in the HOC group than in the LOC group. This results pattern was found to be driven by the specific effects of the reward-signaling distractors, with this finding emerging also when exploring saccade-based measures. Conversely, no group differences emerged for non-distractor error responses. Finally, controlling for both addiction-related compulsivity and depression symptoms did not change these results, strengthening the specificity of current results to OC symptoms.

Current findings are in line with previous studies using the VMAC task to explore reward-related attentional processes in healthy individuals.[27,47,51,52] Specifically, present results showed that across both groups, participants' performance was poorer when high-reward signaling distractors were present, compared to when low-reward signaling distractors were present, which was mainly driven by the reward-signaling distractors (although, as stated above, this effect was stronger in the high OC group). These results replicate extensive prior research showing similar effects, thereby contributing to the establishment and validation of the current eye-tracking-based task as assessing reward-related visual attention capture.

Present results are also in line with the few studies that used the VMAC task to explore compulsivity,[32-34] that showed reward-related attentional capture to be associated with the severity of compulsivity. However, this study elaborates on previous research in several important ways. First, by using an eye-tracking-based task, rather than an RT-based one, we could explore attentional deployment before reaching/fixating the target, including both fixations and saccade data, pinpointing group differences in task performance to the reward-signaling distractors (while also eliminating the motor response-related effects). Relatedly, keypress indices of attention give rise to potential confounding elements related to the execution of the motor response (ie, key-presses), possibly obscuring the interpretation of emergent results.[53] This is especially relevant given the high co-morbidity between OCD and depression,[54-56] which is characterized by psychomotor slowness.[57-59] This limitation was addressed by using an eye-tracking-based version of the task. Third, this study compared two groups of participants based on well-defined cutoff scores, rather than exploring correlations among non-selected participants. Fourth, this study was delivered in a controlled lab setting, rather than being delivered as an online procedure via Amazon Mechanical Turk,[32-34] eliminating concerns regarding data quality of online psychological-related research (eg, sample biases, reduced control and monitoring of data collection, and dropout rates[60,61]). Finally, in prior research the signaling-reward distractors were also physically salient (ie, were the only colored stimulus in the display), and may have "popped out" capturing attention by involving bottom-up processes due to saliency, not necessarily related to their rewarding-signaling value.[48,62-64] Conversely, here, all stimuli used in the search display of this study were uniquely colored, increasing our confidence in attributing emergent findings to the rewarding nature of the reward-signaling distractors, rather than to their physical saliency.

Present findings also echo previous research using the VMAC task to explore attentional capture by reward-signaling cues in addiction. Specifically, these studies show associations between value-modulated attentional capture and addiction disorder

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symptoms (eg, drug and alcohol misuse), with greater attentional capture toward reward-signaling distractors emerging in participants with addiction symptoms, compared to non-addictive participants.[49,65,66] Considering these findings in addiction, conjointly with present findings and the (above-cited) research on VMAC performance and compulsivity, may lend some support to the viewpoint of OCD as a behavioral addiction,[67-69] specifically to the mutual dimension of alterations in reward functioning, for example, [9,10,12,16,70] Yet, the fact that present results remained significant after controlling for addiction-related compulsivity also suggests a specific effect for OCD-related compulsivity, beyond that of addiction. Still, future research could more directly compare the performance of participants with high OC symptoms to that of participants with addictive symptoms.

This study has several limitations that need to be acknowledged. First, the study did not include participants with clinically diagnosed OCD, but a sample of participants with high levels of OC symptoms. Still, we used a high OCI-R cutoff score of 27, reflecting severe OCD,[38] as our inclusion criterion. Also, OCI-R scores were assessed twice, once during initial participant screening and once on the day of study participation, to verify score stability. Finally, using subclinical samples with high scores on measures of OCD has been shown to be relevant to the understanding of the disorder (for a review see[71]), and proven useful in previous research conducted in our laboratory, in which results were later successfully replicated in clinical samples.[39,40] Still, future studies should replicate this study using patients with clinically diagnosed OCD. Second, while sign-tracking behaviors are known to be more resistant to extinction, compared to goal-tracking behaviors,[72-75] the present procedure did not include an extinction block (ie, a block in which distractors no longer predict reward value). Hence, this claim could not be explored. As this was the first study to use the VMAC task among participants with high levels of OC symptoms, we opted to focus on the more basic VMAC effect. Still, future studies may add an extinction block to examine the VMAC effect under extinction conditions. Finally, in the VMAC paradigm rewards are response-dependent, as only correct responses to the target elicit reward delivery. Conversely, in animal studies rewards are response-independent in that they are delivered non-contingent on a specific response (ie, the food will always be delivered). Thus, one could argue that the VMAC task does not entail "pure" sign-tracking.[73] While we chose to use a well-established VMAC task, future studies could better tap pure sign-tracking by using a paradigm in which reward-paired stimuli are both task-irrelevant and response-independent.[73,76]

Conclusion

To conclude, current findings propose that reward-related aberrant attentional functioning may be related to OC symptoms, findings that need to be further elaborated to clinically diagnosed patients with OCD. From a therapeutic standpoint, this may suggest to acknowledge reward functioning, in addition to the traditional anxiety-avoidance aspect of OCD, as part of the psychoeducation phase in current OCD treatments, thereby expanding the patient's understanding of his condition. This may include, for example, an educational reframing of compulsive behaviors not merely as related to obsession-related anxiety, but also to reward-related processes. Specifically, conceptualizing compulsive behaviors as gaining rewarding value through the processes of negative reinforcement —when reducing obsession-related anxiety and/or distress, or when yielding "just right" experiences, resulting in an addictive-like dependency upon these behaviors.[77] This reframing may help patients make sense of their compulsions and decrease negative feelings, such as shame and self-criticism, that usually accompany their self-experience. More speculatively, future research could also explore the extent in which modifying reward-related attentional processes may alleviate OCD and decrease symptoms.[78-80]

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