



Symptom provocation in obsessive-compulsive disorder: Validation of the Braga Obsessive Compulsive image set (BOCIS)

Mafalda Machado Sousa^{a,b,c,1}, Ana Daniela Costa^{a,b,c,1}, Cláudia Almeida^d, Carles Soriano-Mas^{e,f,g,2}, Pedro Silva Moreira^{h,2}, Pedro Morgado^{a,b,c,2,*}

^a Life and Health Sciences Research Institute (ICVS), School of Medicine, University of Minho, Braga, Portugal

^b ICVS-3Bs PT Government Associate Laboratory, Braga, Guimarães, Portugal

^c Clinical Academic Center-Braga (2CA), Braga, Portugal

^d ABC da Psicologia, Porto, Portugal

^e Department of Social Psychology and Quantitative Psychology, Institute of Neurosciences, Universitat de Barcelona, Spain

^f Department of Psychiatry, Bellvitge University Hospital, Bellvitge Biomedical Research Institute (IDIBELL), Barcelona, Spain

^g Centro de Investigación Biomédica en Red de Salud Mental (CIBERSAM), Carlos III Health Institute, Madrid, Spain

^h Psychology Research Centre, School of Psychology, University of Minho, Braga, Portugal

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ABSTRACT

Symptom provocation paradigms are paramount to understand a heterogeneous disorder as obsessive-compulsive disorder (OCD). The main aim of our work was to develop and validate an open-access set of OCD-related images comprising three main subtypes: washing, checking, and symmetry.

Twenty-six OCD patients and 25 controls provided valence and arousal ratings for a set of OCD-related, aversive, and neutral images.

Linear mixed model analyses were used to estimate the main effects of group, image category, and group-image category interaction in image ratings. All main effects were found to be significant for both arousal and valence ratings, except for the group in arousal ratings.

Path analysis confirmed our hypothesis that the OCI-R subscales influenced the subjective ratings of the corresponding image categories, particularly among patients. Independent samples t-tests were performed for each OCD picture to compose the set. Arousal demonstrated a greater capacity to distinguish controls and patients, thus sustaining our choice of using these ratings for the final Braga Obsessive-Compulsive Image Set (BOCIS).

Our study demonstrated that the stimuli of the BOCIS reliably portray OCD-like triggers for washing, checking and symmetry subtypes. Its open-access availability will facilitate significant progress in both clinical and research settings.

1. Introduction

Obsessive-compulsive disorder (OCD) is a common psychiatric disorder characterized by the presence of obsessions (persistent, intrusive, and unwanted thoughts) and/or compulsions (repetitive/ritualistic behaviors or mental acts performed to reduce the anxiety caused by the obsessions), which cause an important impact on patients' daily living (APA, 2013). OCD presentation is very heterogeneous, i.e. has distinct clinical manifestations with at least four identified subtypes:

contamination/washing, harming/checking, symmetry/ordering, and hoarding (Mataix-Cols et al., 2004). The heterogeneity of the disorder and the fact that is frequently accompanied by comorbidities, contributes to its unrecognition, delaying the diagnosis and access to treatment, which significantly impacts the chances of remission and the chronicity of the disorder (Jakubovski et al., 2013).

There has been a growing interest in disentangling the neurobiological mechanisms underpinning the expression of different symptoms in OCD. Neuroimaging research has surfaced as a promising tool to shed

* Corresponding author.

E-mail address: pedromorgado@med.uminho.pt (M.M. Sousa).

¹ Equal contributors to this work as co-first authors.

² Equal contribution.

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Table 1
Sociodemographic and clinical characteristics.

	OCD patients (n = 26)	Controls (n = 25)	Statistic
Gender			
Female	19	17	$\chi^2 (1) = 0.158, p = 0.691$
Male	7	8	
Education			
High school	5	1	$\chi^2 (3) = 0.665, p = 0.084$
University ≤ 3 yrs	9	5	
University > 3 yrs	12	17	
Doctoral	0	2	
Age (Yrs)			
Mean (SD)	32.31 (10.96)	30.04 (6.58)	$U = 308.500, p = 0.381$
Y-BOCS			
Mean (SD)	25.15 (7.07)	–	
OCI-R (Mean (SD))			
Total score	26.15 (13.92)	11.00 (7.63)	$t = -4.794 (49), p < 0.001$
Washing	3.35 (3.84)	1.20 (1.47)	$U = 238.500, p = 0.046$
Checking	3.92 (3.51)	1.56 (1.71)	$U = 200.500, p = 0.009$
Hoarding	3.46 (3.34)	1.84 (1.49)	$U = 242.500, p = 0.058$
Ordering	4.88 (3.53)	3.04 (2.15)	$U = 238.000, p = 0.050$
Obsessing	8.00 (2.86)	2.92 (2.68)	$U = 62.000, p < 0.001$
Neutralizing	2.54 (2.85)	0.44 (1.04)	$U = 171.500, p < 0.001$

light on the pathophysiological mechanisms underlying OCD symptom presentation. Even though the cortico-striato-thalamo-cortical (CSTC) model (Saxena et al., 1998) has been widely implicated in the pathophysiology of OCD, there has been growing evidence suggesting the involvement of other circuits, including fronto-striatal, fronto-parietal, fronto-limbic and cerebellar circuits (Stein et al., 2019).

In order to better understand OCD, inducing symptoms in a controlled environment is of utmost relevance. Therefore, paradigms for symptom provocation (SP) in research must be developed (De Putter et al., 2017). SP tasks typically involve the visualization and evaluation of triggering stimuli. Frequently, emotional stimuli are characterized according to a two-dimensional theory of emotions (Bradley, 2000; Lang et al., 1993), which presents valence and arousal as two fundamental affective dimensions to assess the emotional impact of such stimuli. Particularly, arousal refers to an individual's self-reported sense of heightened physiological and emotional activation in response to a specific stimulus or situation. In the context of SP, which aims to trigger an anxiety response, subjective arousal reflects the individual's perception of feeling anxious and could serve as a direct reflection of their interpretation of the anxious experience.

In the particular case of OCD, SP tasks often present emotional stimuli that mirror daily life situations capable of triggering anxiety and/or the urge for compulsions in patients (e.g. dirty or likely contaminated objects). These tasks can be used in a clinical context, helping patients to employ an adaptive strategy to cope with the distress evoked by the stimuli (Maia et al., 2022; Tendler et al., 2019). In line with this, literature has been pointing out the impact of SP tasks conducted in the context of neuromodulation procedures. Tendler et al. (2019), as well as Maia et al. (2022) published protocols that focus on targeting the brain circuits activated by the symptoms. This specificity attained by conjugating SP and neuromodulation procedures could be translated into better clinical outcomes.

In the field of neuroimaging research, the main aim of SP tasks is to elicit the symptoms that OCD patients experience in everyday life while visualizing their brain activation patterns during the provoked state (Thorsen et al., 2018). A recent meta-analytic aggregation of the literature focused on the brain activation of OCD patients during SP tasks. Although it demonstrated that OCD patients display increased activation

of the dorsal striatum during SP, it also evidences dissociable patterns when assessing subgroups of patients with distinct symptomatic manifestations (Yu et al., 2022). Coupled with the fact that OCD is highly heterogeneous and patients typically present symptoms from more than one subtype, the need to try to uncover symptom-specific phenotypical manifestations may be extremely relevant. The combination of behavioral and neurobiological approaches or data captured during SP may add important robustness to OCD therapies and research, allowing us to attain more objective indicators of the pathophysiology of the disorder and/or response to treatments. Pre-post treatment comparison of the stimuli evaluation and brain activation during their visualization can lead us towards more personalized care (e.g. targeting brain substrates with TMS that are activated with symptomatology) and the definition of predictive models for treatment response - two crucial goals in a disorder as chronic as OCD. Nevertheless, given the heterogeneity of OCD and the fact that the triggers for each patient can be extremely idiosyncratic, it is critical to develop adequate symptom-specific stimuli for fMRI research.

Studies in the field of neuropsychophysiology and neuroimaging often use emotional tasks with visual stimuli. For OCD, there are a few existent image databases developed to study the emotional processing and/or regulation in these patients [i.e. The Maudsley Obsessive-Compulsive Stimuli Set (MOCSS) (Mataix-Cols et al., 2009); The Berlin Obsessive Compulsive Disorder-Picture Set (BOCD-PS) (Simon et al., 2012), and one set targeting solely checking symptoms (Brooks et al., 2018)]. However, some of these sets, namely the MOCSS, only triggered mild OCD symptoms (van den Heuvel et al., 2004). Also, most of the referred sets are non-open access and some of the stimuli could be regarded as outdated, given that they are no longer in use in our daily lives, (e.g. images of public telephones), affecting their emotional impact.

Our main aim is to develop and validate a new standardized image set that will encompass OCD-related triggers regarding the three most common OCD themes: washing, checking, and symmetry. We expect to constitute a stimulus set that is able to trigger higher distress in OCD patients than in healthy controls which could serve as a standardized tool that can reliably induce obsessions and compulsions in individuals with OCD during controlled experiments or therapy sessions. By tailoring the stimuli to specific obsessional themes and compulsive behaviors that commonly manifest in OCD, researchers and clinicians can create a more ecologically valid and clinically relevant environment for symptom provocation. Furthermore, a validated OCD-specific image set facilitates the comparability of research findings across different studies, ultimately improving our understanding of such complex and often debilitating disorder.

2. Methods

2.1. Participants

Twenty-six patients with OCD and 25 healthy controls were recruited from the general community.

Regarding the patients' group, participants had to meet the criteria for OCD as a primary diagnosis, according to the DSM-V (American Psychiatric Association, 2013), and to have a minimum score of 16 on the Yale-Brown Obsessive Compulsive Scale (Y-BOCS) (Goodman et al., 1989). A score of 16 or higher on this scale is usually considered as clinically relevant, evidencing the presence of moderate obsessive-compulsive symptoms.

In both groups, sociodemographic information (i.e. age, sex, and education) was collected, as well as the levels of obsessive-compulsive symptoms which were assessed using the Obsessive-Compulsive Inventory-Revised (OCI-R) (Cunha et al., 2022; Foa et al., 2002).

All participants provided electronic informed consent previously approved by the ethical board of the University of Minho (CEICVS 042/2022).

2.2. Stimuli

Initially, we conducted a brainstorming session with therapists and researchers with expertise in OCD, in which we listed common and relevant objects/scenarios that typically trigger obsessive-compulsive symptoms regarding three main OCD categories: washing, checking, and symmetry. Pictures of these triggers were taken by the authors (MMS and ADC) with a digital camera (Nikon D5300). From an initial larger pool of pictures, 190 were selected (washing (65), checking (64), and symmetry (61)) based on their quality. Pictures were further edited and balanced in terms of brightness, contrast, saturation, and smoothness.

In addition, we added as control conditions 64 aversive and 66 neutral images from two widely used databases, the International Affective Picture System (IAPS) (Lang and Bradley, 2007; Soares et al., 2015), and the Open Affective Standardized Image Set (OASIS) (Kurdi et al., 2017). This selection was based on the valence and arousal criteria established by de Wit (Wit et al., 2015) - neutral (valence $4.5 < x < 7.0$, arousal $2.0 < x < 4.2$) and aversive (valence $x \leq 4.0$, arousal $x \geq 6.0$). As the OASIS set did not have the same 9-point rating scale, a conversion was made to ensure the scores were comparable. Neutral and aversive pictures were also visually inspected to ensure that they did not portray any OCD trigger and that they were in landscape format to avoid clear distinction from the images taken by the authors.

The OCD experts consulted in the brainstorming phase validated the 190 OCD-related pictures selected to be presented to participants and helped resolve conflicts regarding the neutral and aversive pictures portraying potentially triggering stimuli to OCD patients.

2.3. Rating session

All participants rated 320 images during two separate online rating sessions. Stimuli presentation was built using PsychoPy v2022.2.2 (Peirce and MacAskill, 2018) and imported to the online study presentation software - Pavlovia (<https://pavlovia.org/>). OCD-related, aversive, and neutral images were randomly presented for 5 s in full screen for evaluation. Each image was followed by a visual analog scale that allowed participants to rate the images regarding valence (from 1 = “highly negative” to 9 = “highly positive”) and arousal (from 1 = “minimal arousing” to 9 = “extremely arousing”).

2.4. Statistical analyses

Data normality and statistical assumptions were checked with Shapiro-Wilk’s test. Considering the non-normal distribution for the age and obsessive-compulsive symptoms, Mann-Whitney tests were performed to compare OCD patients and healthy controls regarding these variables. The distribution of sex and education level was compared between groups using Chi-squared tests.

Linear mixed model (LMM) analyses were used to estimate the main effects of group (OCD vs. controls), image category (neutral, aversive, washing, checking, and symmetry), and group-image category interaction in image ratings. In these models, valence and arousal were set as dependent variables, diagnosis group, and image category as fixed effects variables, and participant as the random effects grouping variable. Contrasts were defined to further explore statistically significant main/interaction effects, using a multivariate-t correction.

A path analysis was conducted in which we hypothesized that the OCI-R subscales (washing, checking and ordering) influenced the subjective ratings of the corresponding image categories. In line with this, the OCI-R subscales were set as independent variables and the subjective ratings of each image category as dependent variables. The model was estimated using Maximum likelihood.

Additionally, correlation analyses were conducted to explore the associations between OCI-R subscales (washing, checking, ordering, hoarding, obsessing, and neutralizing) and subjective ratings (arousal

and valence) of the images. The results of the correlation analyses are reported as Spearman’s rho when the assumption of pairwise normality was not met. Moreover, patients’ symptom severity, assessed by the Y-BOCS, was also correlated with the subjective ratings in OCD-related stimuli.

To define the Braga Obsessive-Compulsive Image Set (BOCIS), for each image category, all the images were statistically compared between controls and OCD patients with regards to valence and arousal scores using independent samples t-tests. This strategy was used to select the final set of images for each category that best discriminates between the two groups.

All statistical analyses were performed using R (R Core Team, 2020) and Python 3.9.12 considering a p-value of 0.05 for the establishment of statistical significance.

3. Results

3.1. Sociodemographic and clinical variables

Considering the distribution of the sociodemographic and clinical variables, Shapiro Wilk’s test revealed the non-normality of all variables ($p < 0.005$) in both groups, except for the total score in the OCI-R for both patients ($p = 0.37$) and controls ($p = 0.146$), and the Y-BOCS score ($p = 0.110$).

The groups of OCD patients and healthy controls were not significantly different with regards to age ($U = 308.500$, $p = 0.381$), sex ($\chi^2 = 0.158$, $p = 0.691$), and education ($\chi^2 = 6.655$, $p = 0.084$). Patients had significantly higher scores in the OCI-R total score ($t = -4.794$, $p < 0.001$), as well as in the checking ($U = 200.500$, $p = 0.009$), obsessing ($U = 62.000$, $p < 0.001$), and neutralizing ($U = 171.500$, $p < 0.001$) subscales.

Regarding the severity of OCD symptoms, patients presented moderate to severe symptomatology ($Mean = 25.15$, $SD = 7.07$). [Table 1](#)

3.2. Association between image subjective ratings

Through the visual inspection of the plots presented in [Fig. 1](#), we can observe a tendency for lower ratings of valence and higher ratings of arousal in OCD patients when compared to healthy controls. Aversive images yielded higher combined ratings of arousal and valence, whereas neutral images had the lowest ratings in both groups. Furthermore, OCD-related images (washing, checking, and symmetry) present more pronounced differences between groups when compared to the control images (aversive and neutral).

3.3. Linear mixed model analysis

The Linear mixed model (LMM) analysis revealed significant effects for the diagnosis group [$F_{(1, 56.65)} = 5.330$, $p = 0.025$], image category [$F_{(4, 15451.19)} = 3270.9$, $p < 0.001$], and group by image category interaction [$F_{(4, 15451.19)} = 13.153$, $p < 0.001$] on the valence ratings. The estimated marginal mean (EMM) was lower for OCD patients ($EMM_{OCD, val} = 4.391$, $SE = 0.083$) on valence in comparison to healthy controls ($EMM_{HC, val} = 4.117$, $SE = 0.085$). Regarding image category, through the visual inspection of the plot ([Fig. 2](#)) it was noted that aversive images yielded the lowest values ($EMM_{Avers} = 2.410$, $SE = 0.062$) and neutral images yielded the highest means of valence ($EMM_{Neut} = 5.623$, $SE = 0.062$). Considering the OCD-related images, washing images showed the lowest means ($EMM_{Wash} = 4.032$, $SE = 0.062$). [Table 2](#) In line with this, contrasts were conducted to explore which comparisons yielded significant results.

Concerning image categories, all contrasts exhibited statistical significance ($p < 0.001$). These results indicate that aversive images received significantly lower scores for valence compared to all other categories, whereas neutral images were rated significantly higher (*i.e.* more positively) than all other categories. Furthermore, washing images

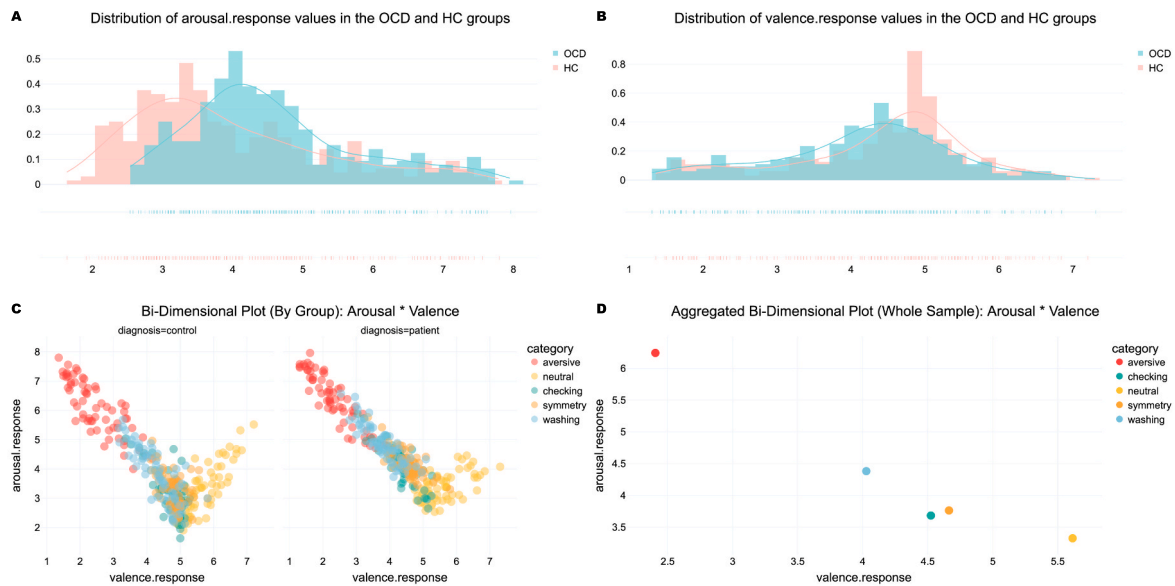


Fig. 1. Distribution of valence and arousal ratings (1 A - Distribution of valence in both groups; 1 B - Distribution of arousal in both groups; 1C - Bi-dimensional plot of arousal \times valence ratings divided by image categories in both groups; 1D - Bi-dimensional plot of arousal \times valence ratings aggregated by image category and group).

were scored significantly lower on valence than checking and symmetry images, while checking images were rated significantly lower than symmetry images. For the group-image category interaction, contrasts showed that OCD patients presented significantly lower scores of valence in checking ($p = 0.009$) and washing images ($p < 0.001$) when compared to controls (detailed information regarding contrasts for the subjective ratings is presented in Supplementary material, [Tables S1-S4](#)).

With regards to arousal ratings, significant effects for image category [$F_{(4, 15461.03)} = 1182.006, p = <0.001$] and group by image category interaction [$F_{(4, 15461.03)} = 35.070, p = <0.001$] were observed. No group effect on the arousal ratings was found [$F_{(1, 49.03)} = 2.040, p = 0.160$]. Aversive images yielded the highest values ($EMM_{Avers} = 6.266, SE = 0.201$) and neutral images yielded the lowest means of arousal ($EMM_{Neut} = 3.344, SE = 0.201$). Within the OCD-related images, washing images were perceived as more arousing ($EMM_{Wash} = 4.394, SE = 0.201$). [Table 2](#) In a similar fashion to the valence ratings analyses, we conducted contrast analyses to further assess the significance of specific comparisons. For detailed information regarding the estimated marginal means of the group by image category interaction, please see [Table 3](#).

Concerning image category, all contrasts reached statistical significance ($p < 0.001$) with the exception of the contrast between checking and symmetry images ($p = 0.273$). Contrasts related to group-by-image category interaction showed that checking images ($p = 0.047$) as well as washing images ($p = 0.036$) have significantly higher scores of arousal in patients with OCD when compared to healthy controls.

3.4. Association between OCI-R subscales and image ratings

3.4.1. Path analysis

Path analysis was performed on both groups (i.e. patients and healthy controls) to test the effect of the obsessive-compulsive (OC) symptoms on the ratings given to OCD-related pictures. Models' fit was assessed according to the Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and χ^2 test and p values. As observed in [Fig. 3](#), the models for arousal for both groups revealed greater fit indices in comparison to the valence models. When considering the model of arousal ratings for patients, each assessment of OCD-related pictures (for checking, washing, and symmetry) was moderately

predicted by the corresponding score on the OCI-R scale - the same pattern was noted when assessing the regression coefficients between OCI-R dimensions and valence ratings. For HC group, significant regression coefficients were obtained from the OCI-R ordering scale to the arousal ratings of symmetry images and from the OCI-R washing scale to the arousal ratings of washing images - however, the observed coefficients were of lower magnitude in comparison to those observed in the OCD group. This pattern was not replicated in valence ratings, where no significant effects of OCI-R dimensions on the corresponding OC image category were found. In both arousal and valence models, there were significant associations between ratings of different image categories.

3.4.2. Correlation analysis

Correlation analyses in the patient group indicated that all subjective ratings regarding OCD-related images correlated significantly with the OCI-R total score and OCI-R ordering subscale. Our results also revealed significant correlations between the valence and arousal ratings of patients to each specific category of OCD-related images and their corresponding levels of symptomatology assessed with the OCI-R subscales. In addition, no significant correlations were found between the subjective ratings and symptom severity (measured by the Y-BOCS), or with the OCI-R obsessing subscale.

Concerning the control group, valence ratings of all OCD-related images correlated significantly with the OCI-R washing subscale. Moreover, valence ratings of symmetry images were significantly associated with the OCI-R total score and its corresponding subscale, as well as with the washing and obsessing subscales. No significant correlations were found with respect to arousal ratings from all OCD-related images (see Supplementary material, [Table S5](#) for detailed correlation results).

3.5. BOCIS dataset

3.5.1. Differences between individual images

Independent t-tests were performed for each OCD-related image to assess which pictures were able to distinguish OCD patients and controls in terms of valence and arousal ratings (OCD patients $>$ Healthy Controls). Concerning valence ratings, 59 OCD-related images reached a significance threshold: 29 washing, 9 symmetry, and 21 checking images were significantly higher rated by OCD patients compared to

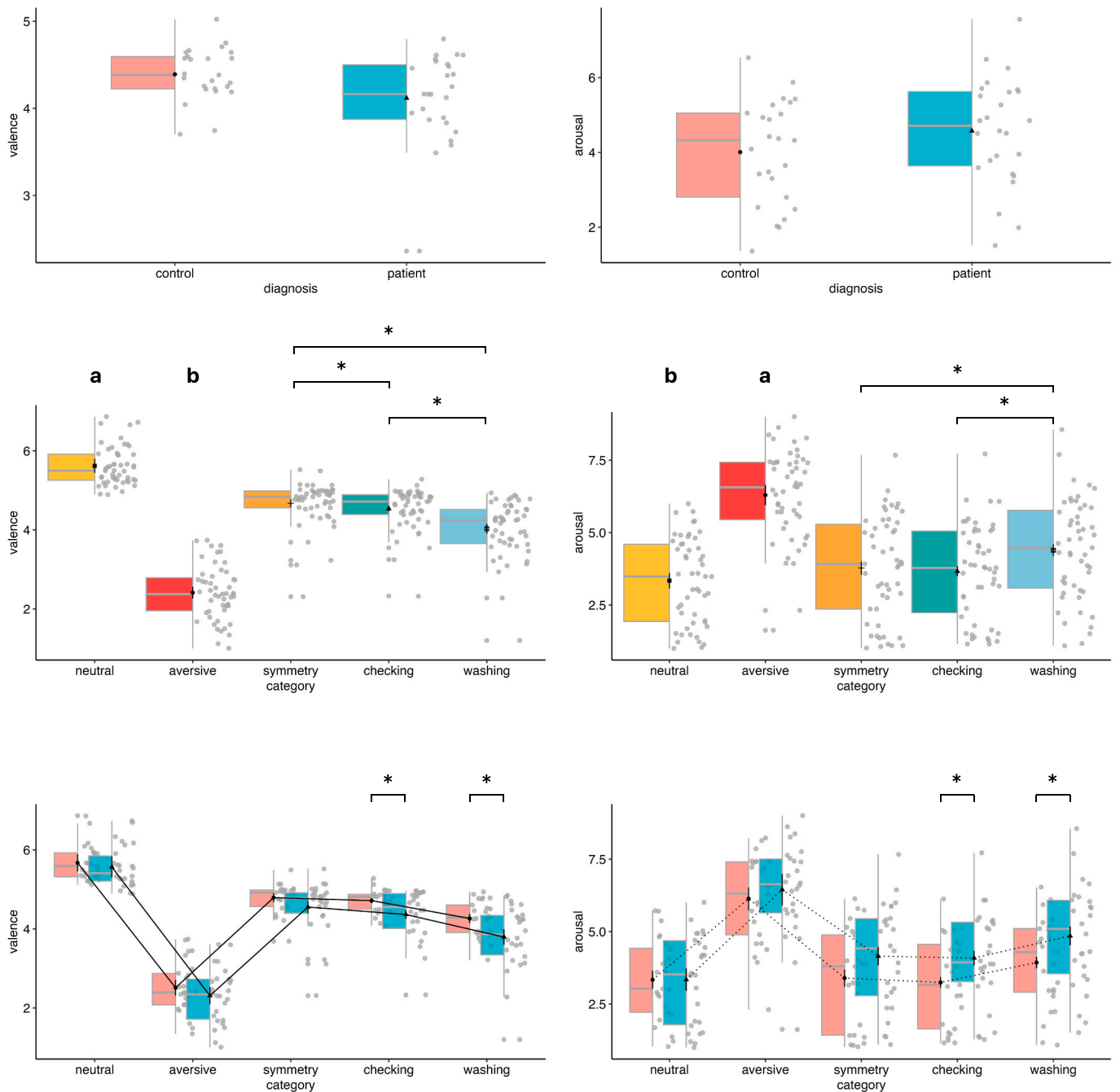


Fig. 2. Linear mixed model results for the subjective ratings.

Table 2
Estimated marginal means of image category for valence and arousal ratings.

Category	Valence			Arousal		
	Estimate	SE	95% CI	Estimate	SE	95% CI
Aversive	2.410	0.062	2.289–2.532	6.266	0.201	5.873–6.659
Neutral	5.623	0.062	5.502–5.745	3.344	0.201	2.951–3.737
Checking	4.536	0.062	4.414–4.658	3.686	0.201	3.293–4.079
Symmetry	4.669	0.062	4.547–4.791	3.774	0.201	3.381–4.168
Washing	4.032	0.062	3.910–4.153	4.394	0.201	4.001–4.787

controls (Supplementary material, Fig. S1). When performing the same analysis for arousal ratings, 73 images were identified as being significantly higher scored in patients compared to healthy controls (27

washing, 27 checking, and 19 symmetry images) (Supplementary material, Fig. S2). The descriptive statistics for each image are reported in the Supplementary material (Table S6).

Table 3
Estimated marginal means of the group by image category interaction for valence and arousal ratings.

Diagnosis	Category	Valence				Arousal			
		Estimate	SE	Lower	Upper	Estimate	SE	Lower	Upper
Control	Aversive	2.494	0.089	2.320	2.668	6.154	0.287	5.592	6.716
Patient	Aversive	2.327	0.087	2.157	2.498	6.378	0.281	5.828	6.929
Control	Neutral	5.678	0.089	5.504	5.852	3.319	0.286	2.757	3.880
Patient	Neutral	5.569	0.087	5.399	5.739	3.370	0.281	2.820	3.920
Control	Checking	4.718	0.089	4.544	4.892	3.252	0.287	2.690	3.813
Patient	Checking	4.355	0.087	4.184	4.525	4.120	0.281	3.570	4.671
Control	Symmetry	4.795	0.089	4.620	4.969	3.389	0.287	2.826	3.951
Patient	Symmetry	4.544	0.087	4.373	4.714	4.160	0.281	3.609	4.711
Control	Washing	4.271	0.089	4.097	4.445	3.935	0.286	3.372	4.496
Patient	Washing	3.792	0.087	3.622	3.963	4.852	0.281	4.302	5.403

Total

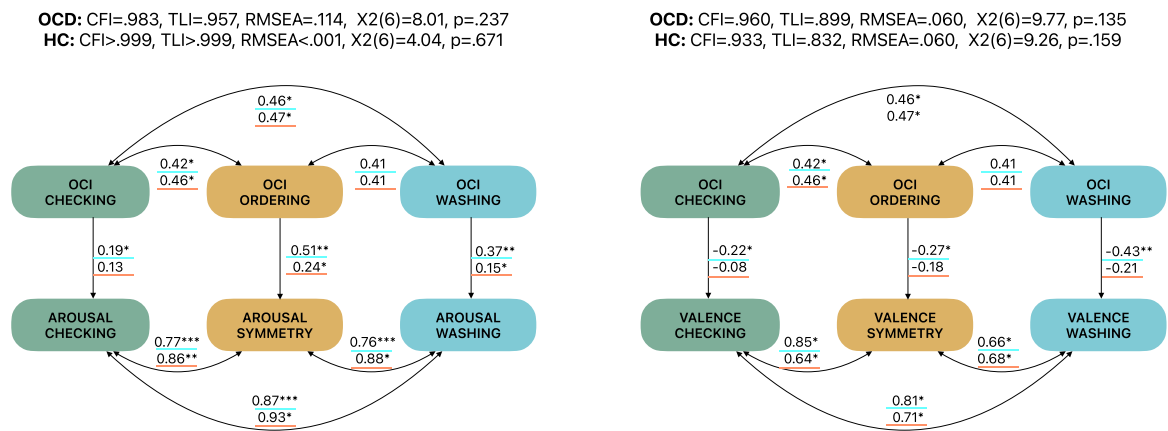


Fig. 3. Path analysis model diagram (values underlined in blue represent the patient group and those underlined in red the control group).

3.5.2. Selection of stimuli

According to the previous analysis, arousal is the affective dimension that produces the highest differences between OCD patients and controls across different image categories. Additionally, the results obtained from the path analysis yielded greater fit indices in relation to OC dimensions for the models with arousal ratings. Considering this, we constituted the final set, using the images with statistically significant differences between OCD patients and healthy controls. The images composing BOCIS are available at <https://osf.io/hzg8r>.

3.5.3. Descriptive statistics and correlation analysis

The raincloud presented in Fig. 4 enables a visual representation of the difference in terms of arousal ratings of the OCD-related images between patients and controls.

Correlation analyses within the patient group indicated that all subjective ratings regarding OCD-related images correlated significantly with the OCI-R total score. Our results also revealed significant correlations between the arousal ratings of each specific category of OCD-related images and the corresponding OCI-R subscale. Furthermore, arousal ratings of all OCD-related images correlated with the OCI-R

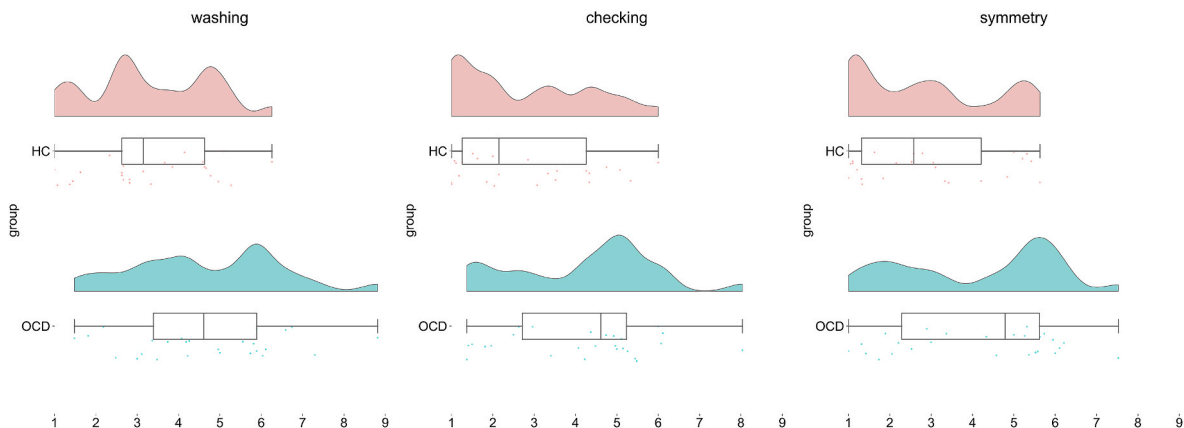


Fig. 4. Raincloud of the distribution of arousal ratings regarding the final images composing BOCIS (OCD patients and healthy controls (HC)).

ordering, hoarding and neutralizing subscales. In addition, no significant correlations were found between the subjective ratings and symptom severity (measured by the Y-BOCS), or with the OCI-R obsessing subscale. Regarding the control group, no significant correlations were found. Detailed correlation results are presented in Table 4.

4. Discussion

The main goal of our work was to develop and validate an open-access set of OCD-related images comprising three main subtypes (washing, checking, and symmetry).

Our results revealed that OCD patients rated images less positively in comparison to healthy controls. It seems that, in general, patients have the tendency to perceive stimuli of the environment as more aversive than the general population (Aigner et al., 2007). This negative bias may be accounted for by the deficits in ventral affective areas described as part of OCD pathophysiology (Thorsen et al., 2018). However, our results did not reveal an effect of diagnosis on arousal ratings, demonstrating that our patients do not appear to have altered responses to possible threats. Although these results were consistent with those found in Simon et al. (2012), this seems to be contradictory to the phenotype of OCD. In fact, it is this misinterpretation of intrusive thoughts and/or situations of everyday life as dangerous that maintains the dysfunctional cycle of OC symptoms, i.e. making patients perform the compulsions after facing the objects of their fears (APA, 2013). However, this is not a unique explanation. The main effect of diagnosis reported in our LLM section accounts for all the picture categories, thus, having neutral and aversive pictures influencing the clear distinction in activation between groups for OCD-related pictures.

Significant interaction effects of diagnosis and picture category were only observed for the washing and checking image ratings, suggesting that within our stimulus set, washing and checking images were more relevant to patients. Conversely, symmetry images did not present this effect, possibly due to the fact that these types of behaviors are seen as normative to the general population while the presence of chaos and disorganization are viewed as disruptive. In fact, Radomsky and Rachman (2004) state that humans have a strong preference for order, from an aesthetic and adaptive standpoint, helping us navigate complex and constantly changing environments. Looking at the associations between the OC symptoms and the ratings we could corroborate that idea. In patients, the severity of ordering symptoms was found to be significantly associated with all the ratings, evidencing the overlap between ordering and other OC symptoms.

When considering the association between the subjective ratings of patients and their symptom severity, we found that the total severity of OC symptoms correlated with all the ratings of OCD-related images. Thus, patients with greater symptom severity evaluated OCD pictures as more negative and more arousing. Additionally, when examining the correlations between the ratings of each OCD picture category and the symptom subtypes, it was found a significant association between the

category of images and its corresponding OCI-R subscale score. This could indicate that our image set represents symptom-specific triggers for OCD patients and provides evidence of construct validity of these images.

In contrast, our results yielded less specific associations between subjective ratings and some OCI-R subscales. We identified a pattern of positive association between potentially threatening scenarios (i.e. correlation with the arousal scores of OCD-related pictures) and hoarding and neutralizing symptoms. This is consistent with the exacerbated sensitivity to anxiety and intolerance to uncertainty displayed by patients with hoarding disorder, underlying their decision-making difficulties when it comes to discarding items (Castriotta et al., 2019). Furthermore, given the arousing nature of washing and checking pictures, as well as the relevance of these to patients already discussed, that explains the association with the need to employ cognitive strategies to deal with the discomfort. These results were not found in previous studies regarding the validation of OCD stimuli sets, thus future research should further explore the extent of such associations.

Similarly to what was found in Simon et al. (2012), the rating scores of patients did not exhibit a significant correlation with the severity of symptoms assessed with the Y-BOCS. This may be understandable when considering that total severity as assessed by the Y-BOCS does not necessarily translate into greater aversion to OC-like triggers. In fact, the Y-BOCS score evidences only the time spent with OC symptoms, the interference caused in people's lives, and the distress caused by the content of patients' obsessions and compulsions (Woody et al., 1995). On the other hand, the OCI-R scale evaluates specific obsessive-like behaviors that visual triggers, such as the case of our picture set, can comprehensively portray.

Concerning the final images composing BOCIS, our results evidenced the capacity of the stimuli developed to trigger symptoms in OCD patients. In regards to aversive and neutral images, no significant differences were found in the subjective ratings between groups demonstrating that these constituted adequate control for validation of the stimulus set. Within the dimensional theory of emotions employed, we could prove that the arousal approach offers a better approximation to the concept of anxiety. The results for the arousal ratings demonstrated a clear distinction between patients and healthy controls. The correlations performed to the images of the final set highlight this group effect and confirm the reliability of our set to portray disorder-specific scenarios.

4.1. Limitations and future directions

Considering the sample size and the fact that the clinical and sociodemographic data did not meet all the statistical assumptions, results should be interpreted with caution. In this study, we implemented a comprehensive statistical approach to compare OCD-relevant stimuli between OCD patients and healthy controls. Due to the exploratory nature of this investigation, we did not perform a power analysis for

Table 4
Correlations between obsessive-compulsive symptoms and arousal ratings (final images composing BOCIS).

Variable	OCD			Controls		
	Arousal Washing	Arousal Checking	Arousal Symmetry	Arousal Washing	Arousal Checking	Arousal Symmetry
OCI-R total	0.542 ^b	0.531 ^b	0.566 ^b	0.317	0.275	0.35
OCI-R washing	0.455 ^a	0.236	0.181	0.065	0.091	0.09
OCI-R checking	0.334	0.441 ^a	0.339	0.167	0.179	0.294
OCI-R ordering	0.505 ^{b,d}	0.472 ^a	0.679 ^c	0.040	-0.020 ^d	0.151
OCI-R hoarding	0.415 ^a	0.451 ^a	0.513 ^{b,d}	0.297	0.275	0.332
OCI-R obsessing	0.023	0.085	0.201	0.232 ^d	0.227 ^d	0.209 ^d
OCI-R neutralizing	0.482 ^a	0.535 ^b	0.433 ^{a,d}	0.294 ^d	0.167 ^d	0.157 ^d

^a p < .05.

^b p < .01.

^c p < .001.

^d Spearman's rho.

determining the adequate sample size for this research. However, our sample size is within the range of previous studies covering the validation of picture sets for OCD research (Mataix-Cols et al., 2009, n = 33; Simon et al., 2012, n = 13; Brooks et al., 2018, n = 15). Furthermore, the comparisons between individual images were not corrected for multiple comparisons with the goal of maximizing the sensitivity of the analyses. We recognize that this approach has the potential to increase the probability of Type I errors. As such, the results regarding the comparisons between individual images should be interpreted with caution - subsequent research using larger sample sizes and using more stringent statistical methods may constitute a more conservative validation of the findings reported in this manuscript.

Additionally, we used a convenience sample in which patients were not screened based on their symptom presentation (i.e. the presence of one of our three subtypes of interest as the main OCD presentation), but were mainly characterized in terms of their symptom phenotype using the OCI-R scale. Although our image set targets triggers from three main OCD themes (washing, checking, and symmetry), these stimuli might not be distressing to all patients with OCD given the variety of symptom presentations. Therefore, our set can be used solely or in combination with other sets in order to offer a tailored representation of their symptoms. The impact of conducting individualized SP protocols was demonstrated in a meta-analysis conducted by De Putter et al. (2017) which reviews different approaches to SP. In line with this, validation of stimuli targeting other OCD subtypes is needed.

Furthermore, we did not collect information regarding patients' disease duration, an important covariable, that should be addressed in future studies. That coupled with the disease severity can have a great impact on the emotional processing of OCD triggers.

Additionally, the fact that the image rating sessions were conducted online could imply a lack of control of the participants' environment which may lead to unintended distractions or contextual factors that can affect the perceived intensity of symptoms. Furthermore, the quality of the image presentation may differ across devices and screen sizes, impacting the consistency of the experiment. Moreover, the use of pictures to elicit symptoms of a given disorder can be reductive. A static stimulus lacks ecological validity and the ability to capture the immersive context and complexity of the triggers of psychiatric conditions. In future studies, efforts should be made to develop virtual reality-based scenarios that could elicit higher immersion feelings and embodiment resulting in more activating emotional responses to images as demonstrated in previous studies (Estupiñán et al., 2014; Gall et al., 2021). Also, physiological data (i.e. skin conductance, heart rate variability) should be considered in future research, in order to further assess participant's subjective ratings and to comprehensively evaluate the physiological response to emotional stimuli.

4.2. Conclusion

This set of visual stimuli is crucial for research aimed at uncovering the neurobiological underpinnings of OCD through advanced in vivo brain imaging techniques. By providing a rigorously updated and validated set of stimuli capable of accurately and consistently evoking emotionally significant states pertinent to OCD, researchers can delve deeper into the cerebral dysfunctions related to the disorder. Likewise, this approach may also facilitate not only a better understanding of how patients react to various treatments, but may also shed light on the dynamics behind symptom severity fluctuations and chronicity. Moreover, the availability of such validated stimuli is key to ensuring that neuroimaging studies focusing on symptom provocation are comparable in multicentric settings.

Additionally, the fact that BOCIS pictures and validation data will be available in open access will foster its application in clinical and research settings and thus possible advances in the field.

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CRedit authorship contribution statement

Mafalda Machado Sousa: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Ana Daniela Costa:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Cláudia Almeida:** Visualization, Resources. **Carles Soriano-Mas:** Writing – review & editing, Visualization, Validation, Supervision. **Pedro Silva Moreira:** Writing – review & editing, Validation, Supervision, Software, Methodology, Formal analysis. **Pedro Morgado:** Writing – review & editing, Visualization, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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