**SUMMARY**

Intrusive thoughts are characteristic of psychological disorders; attempts to cope can become maladaptive perpetuating the problem (e.g., thought suppression), while others can provide long-term symptoms relief (e.g., acceptance). Although emerging research begins to explore the neural correlates of these strategies in healthy population, it is important to explore these strategies in populations more likely to naturally attempt to use such strategies (clinical symptoms). The present study explored if the use of cognitive strategies to manage intrusive cognitions would be differentially reflected in psychophysiological measures (i.e., error-related negativity) of individuals characterized by obsessive-compulsive symptoms – a group commonly associated with suppression efforts – relative to a low OC control.

67 participants with high and low OC symptoms were randomly assigned to cognitive strategy (suppression or acceptance). Participants watched an emotion-eliciting video clip and used the assigned cognitive strategy while performing the Stroop task. EEG data was collected.

Consistent with well-established and emerging literature, ERN was enhanced in individuals with high OC symptoms and a marginal effect of thought-control strategy was observed, such that ERN amplitude was reduced in the suppression condition and greater for the acceptance condition. Uniquely, the study expanded on emerging literature by exploring whether the relationship between ERN and cognitive strategies was moderated by OC level. Although results were not conclusive, these preliminary findings represent an important first step to study effects of suppression and acceptance on the ERN in a sample characterized by clinically-relevant symptoms and overall encourage further exploration.

**Key words:** ERN; OCD; intrusions; suppression; acceptance
INTRODUCTION

Intrusive thoughts are characteristic of psychological disorders such as obsessions in obsessive-compulsive disorder (OCD), intrusive memories in post-traumatic stress disorder, worry in generalized anxiety disorder, and rumination in major depressive disorder. As a maladaptive coping strategy, individuals attempt to manage these negative intrusions using thought control strategies (e.g., thought suppression; Hoyer, Becker, & Roth, 2001) that often paradoxically exacerbate the problem and maintain psychological disorders (Hayes, Wilson, Gifford, Follette, & Strosahl, 1996; Wegner, 1994). As such, exploring neurophysiological correlates of thought control strategies is crucial to elucidate the mechanisms through which they contribute to psychopathology and inform how treatments may be enhanced. The anterior cingulate cortex (ACC) has been linked with thought suppression strategy use (Deckersbach, Dougherty, & Rauch, 2006; Mitchell et al., 2007; Wyland, Kelley, Macrae, Gordon, & Heatherton, 2003) as well as strategies of mindfulness and acceptance (Tang, Hölzel, & Posner, 2015; Tang & Posner, 2009). The current study used event-related brain potentials (ERPs) thought to be generated in the ACC to examine the impact of two strategies for dealing with intrusions – thought suppression and acceptance – in a sample of individuals characterized by intrusive thoughts (i.e., obsessions). Extending emerging literature exploring ERPs and mindfulness strategies, our goal was to examine whether ERPs could be used as neurophysiological correlates of thought control strategies in individuals with differing levels of obsessive compulsive (OC) symptomatology. More broadly, this furthers understanding of thought control strategy mechanisms consistent with a neuroscience-informed classification system [e.g., Research Domain Criteria (RDoC); Cuthbert & Insel, 2013].

An individual’s motivation to suppress appears to differ across psychological disorders depending on the perceived acceptability of and resistance to intrusive thoughts (Wenzlaff & Wegner, 2000). In those with OCD, thought-action fusion (i.e. thought is akin to conducting the action) motivates suppression of obsessional thinking leading to an initial reduction in intrusive thoughts. However, later the suppressed thought becomes hyper-accessible, leading to a paradoxical delayed increase of thought frequency (i.e., rebound effect; Wegner, 1994) and resulting in increased anxiety following thought suppression (Magee, Harden, & Teachman, 2012). An alternative thought control strategy is acceptance, defined as an active and conscious embrace of intrusive thoughts without attempting to change them (Hayes, Luoma, Bond, Masuda, & Lillis, 2006). Notably, acceptance has instead been associated with decreased distress (Marcks & Woods, 2005) and used in efficacious third-wave transdiagnostic behavioral treatments such as acceptance and commitment therapy (ACT), where mindfulness strategies play a key role (Powers, Zum Vörde Sive Vörding, & Emmelkamp, 2009).

Preliminary evidence suggests an association between thought control strategies and the ACC – an area implicated in executive control, attention, response monitoring, and handling emotional evaluation of events and actions that require
more cognitive control (Bush, Luu, & Posner, 2000). Controlling aversive internal experiences can activate the ACC, as fMRI studies reveal greater ACC activity during a thought suppression condition relative to freely thinking (Wyland et al., 2003). Furthermore, consistent with neural models of cognitive control, the ACC is believed to work in conjunction with the prefrontal cortex (PFC) during thought suppression so that PFC is activated with bilateral ACC showing transient increases associated with the presence of intrusions (Mitchell et al., 2007). Although, less evidence is available directly investigating acceptance as a thought control strategy, several studies have explored the neural correlates of mindfulness – which is a crucial component of acceptance-based treatments and involves awareness of the present moment often integrating a radical acceptance stance. Perhaps given its role in enabling executive attention and control, the ACC has been consistently linked to effects of mindfulness training (Tang et al., 2015), albeit with mixed findings regarding the directionality of its activation (Hölzel et al., 2007; Ives-Deliperi, Solms, & Meintjes, 2011; Ritskes, Ritskes-Hoitinga, & Stødkilde-Jørgensen, 2004; Tang & Posner, 2009; Teper & Inzlicht, 2013).

The negativity error (Ne; Falkenstein, Hohnsbein, Hoormann, & Blanke, 1990, 1991), also later referred to as error-related negativity (ERN; Gehring, Goss, Coles, Meyer, & Donchin, 1993), is a negative ERP occurring 50-100ms after a mistake thought to be generated by the ACC (Perri, Berchicci, Lucci, Spinelli, & Di Russo, 2015; Taylor, Stern, & Gehring, 2007; Van Veen & Carter, 2002). This ERP, henceforth referred to as the ERN, may be a tool to investigate thought control and acceptance-based strategies. For instance, meditators displayed greater executive control, as measured by the Stroop, and emotional acceptance as well as an enhanced ERN relative to non-meditator controls (Teper & Inzlicht, 2013). Similarly, Saunders, Rodrigo, & Inzlicht (2016) found an enhanced ERN following a concentrative and emotion-focused meditation period, although these higher ERN amplitudes were not observed for those performing a thought-focused meditation. Although this would suggest that mindfulness and perhaps acceptance-based strategies would likely lead to enhanced ERN, Larson, Steffen, and Primosch (2013) found no differences in ERN amplitudes when comparing healthy non-meditators randomly assigned to a brief mindfulness intervention or a control condition. While findings are mixed when looking at the effects of acceptance-based strategies on the ERN, literature is scarce considering the effects of other thought control strategies, such as suppression. One study comparing healthy individuals instructed to suppress their emotions while watching a sad movie, adopt a neutral/objective stance, or to simply watch the movie found the suppression group showed a reduced ERN relative to those in the re-appraisal or control group (Wang & Yang, 2014).

Although these studies provide some early support for the ACC as a neural correlate of thought suppression and acceptance-based strategies, the findings are mixed with most of these studies recruiting healthy participants and randomly assigning them to a task-based condition. Given the potential clinical implications
of this research, it is crucial to explore these effects within a population that would more readily engage in thought suppression or presumably benefit from engaging in acceptance-based strategies. The ERN may be ideally suited for this next step given that clinical populations believed to have an overactive performance monitoring system, such as OCD, have been characterized by hyperactivity in the ACC (Fitzgerald et al., 2005), as well as enhanced ERN amplitudes, during error commission and in high conflict trials (Gehring, Himle, & Nisenson, 2000; Roh, Chang, Yoo, Shin, & Kim, 2017). Initial evidence proposes that enhanced error signals in individuals with OCD are associated with the feeling that something is wrong and action is needed to correct the problem (Gehring et al., 2000), with enhanced ERN amplitudes being proposed as a state-independent marker in OCD (Endrass & Ullsperger, 2014). The ERN could also serve as an endophenotype for anxiety and particularly worry, given that these findings have been replicated in other anxiety-related presentations (Moser, Moran, Schroder, Donnellan, & Yeung, 2013; Proudfit, Inzlicht, & Mennin, 2013). Given strong evidence suggesting ACC hyperactivity in individuals with OCD, examining individuals with OC traits would appear to provide an ideal sample to expand on findings from Wang and Yang (2014) by exploring the effects of thought suppression and acceptance on their intrusive cognitions in a sample more likely to naturally engage in thought control strategies.

The purpose of this study was to expand on existing literature by comparing acceptance and suppression conditions in individuals with high OC traits relative to a low OC control to gain some insight as to whether these clinically very different approaches would engage similar neurophysiological systems during a modified emotional Stroop task. Consistent with the literature, it was hypothesized that: 1) an enhanced ERN would be observed in individuals with high OC traits relative to the low OC control; and 2) individuals engaging in acceptance condition would be associated with an enhanced ERN relative those in the suppression condition. Additionally, the study sought to explore whether thought control strategies would be differentially reflected in the ERN in individuals with elevated OC symptoms relative to the low OC control. Behaviorally, a slower reaction time was predicted for participants suppressing intrusive thoughts in response to intrusion-related words during the modified emotional Stroop task (Wegner, Erber, & Zanakos, 1993).

**METHODS**

**Participants**

All participants were screened based on their scores in the Obsessive-Compulsive Inventory-Revised (OCI-R), an 18-item scale that assesses severity of obsessive and compulsive characteristics (Foa et al., 2002). The OCI-R was designed to be administered to both clinical and non-clinical populations, with a clinical cutoff of 21; it is a well-validated and reliable instrument for the measurement of
obsessive and compulsive (OC) symptoms (Foa et al., 2002; Hajcak, Huppert, Simons, & Foa, 2004). In order to consider the effects of thought suppression and acceptance on OC symptoms participants were recruited from the top 12% of the OCI-R distribution of a total of 1,072 screened participants, with the bottom 12% of the distribution serving as a non-OC control. A total of 83 college students enrolled in an introductory psychology course at the University of Arizona participated in the study for partial course credit. Exclusion criteria included history of significant head injury, stroke, epilepsy, electroconvulsive therapy, or current use of psychotropic medications.

Data from 16 participants were excluded from all analyses due to: participants reporting use of medication (n = 1), excessive bad channels (n = 11), participant disengagement (e.g., sleeping during task; n = 2), or other technical difficulties (n = 2). This resulted in a final sample of 67 participants (35 female, 32 male). Scores on the OCI-R of the recruited participants were rank ordered, paired with the next highest score, and then one member of each pair was randomly assigned to either the thought suppression or the acceptance group to ensure an equivalent distribution of OC scores in each condition (31 High OC, 36 Low OC; 34 Accept, 33 Suppress). Table 1 summarizes the OC characteristics of the participants.

### Procedure

After providing informed consent, participants were fitted with an EEG electrode cap. Each participant was given detailed task instructions then seated in front of the computer monitor to view the video clip. Participants watched a 1.5 min video clip from the movie *Trainspotting*. The scene was a vivid depiction of a character using “the worst toilet in Scotland,” and was intended to create intrusive thoughts and images associated with the emotion of disgust.

Next, participants either received thought suppression or acceptance instructions for thoughts related to the video clip, mirroring the protocol used by Marcks and Woods (2005). Participants sat quietly for a five-minute rest period and attempted to use their assigned strategy. Participants indicated the frequency of intrusions by pressing the button of the response device each time they noticed an intrusive thought. Participants were then instructed to continue using the cognitive strategy while performing the Stroop task and placing equal emphasis on
speed and accuracy in their responses. Upon completion, participants were asked to rate on a 1-4 Likert scale: 1) effort at suppressing thoughts, 2) discomfort with their thoughts, and 3) level of acceptance with their thoughts about the video (Marcks & Woods, 2005).

**Task**

The Stroop task was displayed on a monitor using DMDX software (Forster & Forster, 2003) where written instructions were accompanied with a verbal narration. Participants were given a practice trial to ensure familiarity with the task. Throughout the task, participants were shown words presented either in red or blue font using a gray background. A fixation cross preceded each word. Participants held two response devices and were instructed to press the right button when viewing red words and the left button when viewing blue words, or vice versa, counterbalanced across blocks of trials within participants. The words were either neutral (candles, discover), disgust words related to the video (feces, rancid), or the words “left” or “right”. To increase the difficulty of the task and increase the probability of incorrect responses, participants were instructed to ignore the word color of “left” and “right”, and instead to press the corresponding button on the response device. In half of the cases the direction of the presented word (left or right) would be congruent with the current response rule (e.g. “LEFT” in blue, press left for blue words), in the other half it would be incongruent (e.g. “LEFT” in blue, press right for blue words). This design yielded four categories of words to which participants responded: neutral, disgust, congruent, and incongruent. The participants received 4 blocks of 240 words each (960 total trials) with each block containing one-third neutral words, one-third disgust words, and one third left/right words (one-sixth congruent and one-sixth incongruent with response rule). The words were presented for 200 ms at random intervals between 2000 and 2400 ms, in order to prevent expectancy effects. Only the first 3 blocks of trials in the Stroop task were analyzed (first 720 trials) due to degraded behavioral data quality that increased EEG noise-to-signal ratio as a result of participant fatigue.

**Psychophysiological Recording and Data Reduction**

Brain electrical activity was recorded at 25 scalp sites and two mastoid channels in a standard electrode cap referenced to CZ online using a Synamps amplifier (Charlotte, NC). Additionally, three ocular channels recorded horizontal and vertical eye-movements. The EEG was digitized at 1000 Hz continuously during the experiment, amplified by a gain of 500, and band-pass filtered online at 0.05 and 200 Hz. Impedances were kept below 5kΩ.

EEG files were inspected visually and artifacts were removed from the data file. Consistent with previous authors’ work, continuous EEG data were digitally filtered (1.5-15 Hz) using a 3003-point finite impulse response filter and then 12.5 Hz low pass filter. Data were re-referenced offline to linked mastoids; and the EOG sites were re-referenced offline to the nasion. An EOG correction procedure was
then utilized to remove any remaining ocular artifact (Semlitsch, Anderer, Schuster, & Presslich, 1986). To quantify the ERN the continuous EEG file was combined with the behavioral data and then segmented into 500ms epochs, beginning 100ms before each response. Each epoch was baseline-corrected by subtracting the average value of the EEG 50ms before the response from the entire epoch. EEG epochs were averaged by condition to yield error- and correct-trial ERPs for each condition and electrode site; two midline sites (Fz and Cz) were the primary candidates for analysis, as these sites surround the typical maximal ERN amplitude location. The amplitude for correct and error trials were defined as the mean activity occurring in a 50 ms window centered on the largest peak at Cz in the 0-120 ms post-response window. To plot the scalp maps, difference wave forms were created by subtracting the signal on correct trials from that elicited on erroneous trials. Four additional participants were excluded from ERP analyses due missing data, and two participants were excluded due to insufficient errors during the Stroop task (i.e., six, see Olvet & Hajcak, 2009). Additionally, during testing of model’s assumption data from two more participants were identified as outliers (scores 5 standard deviations above the mean and violation of residuals distribution), resulting in a final $n = 59$ for psychophysiological analysis (High OC Acceptance= 13, High OC Suppression= 14, Low OC Acceptance=15, Low OC Suppression=17). Whenever possible, both conventional tests of statistical significance and measures of effect size are reported. Partial $\eta^2$, specifically, is a measure of the proportion of variance that the independent variable accounts for in the dependent variable when the effects of other independent variable and interactions are partialed out. Convention suggests partial $\eta^2$ of .01 = small, .06 = medium and .13 = large, referring to the magnitude of the effect (Richardson, 2011).

**RESULTS**

**Preliminary Analyses**

The effect of the acceptance/suppression instructions and high/low-OC status on frequency of self-reported intrusions during the 5-minute rest period was examined with a two-way ANOVA. In line with literature suggesting that suppression is an effective short-term strategy, there was a main effect of thought control ($F_{1,63} = 5.15, p = .03, \text{partial } \eta^2 = .08$), with the suppression group reporting fewer intrusions than the acceptance group. A main effect of OC severity was also observed ($F_{1,63} = 9.05, p = .004, \text{partial } \eta^2 = .13$), suggesting significantly fewer intrusions for the low-OC group than the high-OC group. The interaction was not significant ($p = .64, \text{partial } \eta^2 = .004$). Additionally, the suppression group reported greater effort at suppressing their thoughts, ($F_{1,67} = 9.34, p = .003, \eta^2 = .129$). Although the suppression group self-reported more discomfort than the acceptance group, the effect was not significant ($F_{1,63} = 1.92, p = .17, \text{partial } \eta^2 = .03$). Similarly, the acceptance group reported a non-significantly higher level of acceptance ($F_{1,62} = 1.42, p = .20, \text{partial } \eta^2 = .027$). For discomfort only, there was a significant main
effect of OC level ($F_{1,62} = 9.05, p = .004, \text{partial } \eta^2 = .13$; all others partial $\eta^2 < .02$). OC level did not interact with acceptance or suppression instructions (partial $\eta^2 < .004$). Means and standard deviations are displayed in Table 2.

The correlations between these self-reports (ignoring group assignment) were calculated to observe patterns of responses. Greater effort at suppressing thoughts was associated with higher discomfort ($r(66) = .26, p = .04$), while discomfort was inversely correlated with self-reported level of acceptance ($r(65) = -.24, p = .05$). No other correlations were significant.

**Stroop Task.** Reaction time and accuracy data for the Stroop task are presented in Table 3.

There were no significant differences between groups in accuracy and reaction times. Consistent with expectation for the Stroop task, participants reacted more quickly during error responses than correct responses ($F_{1,62} = 5.05, p = .03$, partial $\eta^2 = .08$). There was no interaction between correct vs. incorrect trials and either OC group ($F_{1,62} = .44, p = .51$, partial $\eta^2 = .007$) or thought control strategy group ($F_{1,62} = .26, p = .26$, partial $\eta^2 = .02$). The average post-error slowing (Error RT = 540 ms, Post-error RT = 602 ms) was significantly longer ($F_{1,63} = 91.53, p = < .001$, partial $\eta^2 = .59$) than post-correct (Correct RT = 557 ms, Post-correct RT = 547 ms). This compensatory effect was not dependent on OC group status ($F_{1,63} = .47, p = .50$, partial $\eta^2 = .01$) or the thought control strategy condition ($F_{1,63} = .08, p = .78$, partial $\eta^2 = .001$), but their interaction was significant ($F_{1,63} = 4.44, p = .04$, partial $\eta^2 = .07$). Post hoc comparisons showed that for the sup-

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Table 2. Mean and standard deviation of self-reported intrusions and experiences at rest

<table>
<thead>
<tr>
<th># of Intrusions</th>
<th>Suppress</th>
<th>Accept</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>High OC</td>
<td>12.53 (7.42)</td>
<td>16.13 (11.14)</td>
<td>14.36 (9.54)</td>
</tr>
<tr>
<td>Low OC</td>
<td>5.56 (5.23)</td>
<td>11.06 (8.08)</td>
<td>8.31 (7.26)</td>
</tr>
<tr>
<td>Combined</td>
<td>8.73 (7.14)</td>
<td>13.44 (9.83)</td>
<td>11.12 (8.87)</td>
</tr>
</tbody>
</table>

**Likert Scale (1-4)**

<table>
<thead>
<tr>
<th>Effort at suppression</th>
<th>High OC</th>
<th>Low OC</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.87 (1.19)</td>
<td>2.19 (0.83)</td>
<td>2.52 (1.06)</td>
</tr>
<tr>
<td></td>
<td>2.67 (0.97)</td>
<td>1.94 (0.73)</td>
<td>2.31 (0.92)</td>
</tr>
<tr>
<td></td>
<td>2.76 (1.06)</td>
<td>2.06 (0.78)</td>
<td>2.40 (.99)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of discomfort</th>
<th>High OC</th>
<th>Low OC</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.07 (1.16)</td>
<td>1.56 (0.89)</td>
<td>1.81 (1.05)</td>
</tr>
<tr>
<td></td>
<td>1.72 (0.75)</td>
<td>1.61 (0.85)</td>
<td>1.67 (.79)</td>
</tr>
<tr>
<td></td>
<td>1.88 (0.96)</td>
<td>1.59 (0.86)</td>
<td>1.73 (.91)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of acceptance</th>
<th>High OC</th>
<th>Low OC</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.47 (0.83)</td>
<td>2.81 (0.83)</td>
<td>2.65 (.84)</td>
</tr>
<tr>
<td></td>
<td>2.65 (1.00)</td>
<td>2.89 (0.96)</td>
<td>2.77 (.97)</td>
</tr>
<tr>
<td></td>
<td>2.56 (0.91)</td>
<td>2.85 (0.89)</td>
<td>2.71 (.91)</td>
</tr>
</tbody>
</table>

Note. N=67. a = Among those in the suppress condition, those with high OC reported significantly greater intrusions than those with low OC. b = For low OC participants, more intrusions were reported in the acceptance condition compared to the suppress. c Low OC participants reported greater effort to suppress thoughts in the suppression condition compared to the acceptance condition.

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Zambrano-Vazquez et al. Suppression, Acceptance, and ERN in OC
pression group, reaction times were marginally slower for the high OC group compared to the low OC group \((p = .06)\). The number of self-reported intrusions was not associated with post-error slowing \((r (66) = .15, p = .24)\).

Reaction times as a function of group status and stimulus type are depicted in Figure 1, and were analyzed with a 2 (High/Low OC) X 2 (Accept/Suppress) X 4 (Condition: Neutral, Disgust, Congruent, Incongruent) repeated measures ANOVA on correct trials only. As expected, there was a significant main effect of condition, \((F_{3, 63} = .5876, p < .001, \text{partial } \eta^2 = .74)\). There were no main effects for thought control strategy \((F_{1, 63} = .01, p = .92, \text{partial } \eta^2 < .001)\) or OC level

### Table 3. Mean and standard deviations for accuracy and reaction times during Stroop task

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Reaction time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of Errors</td>
<td>Range*</td>
</tr>
<tr>
<td>High OC</td>
<td>29.52 (19.97)</td>
<td>5-79</td>
</tr>
<tr>
<td>Low OC</td>
<td>23.47 (14.83)</td>
<td>1-56</td>
</tr>
<tr>
<td>Suppress</td>
<td>26.12 (16.98)</td>
<td>10-74</td>
</tr>
<tr>
<td>Accept</td>
<td>26.41 (18.28)</td>
<td>1-79</td>
</tr>
<tr>
<td>Total Sample</td>
<td>26.27 (17.52)</td>
<td>6-79</td>
</tr>
</tbody>
</table>

Note. \(N = 67\), *Two participants had less than six errors and were excluded from the ERP analyses following recommended guidelines (Olvet & Hajcak, 2009).
(F\textsubscript{1,63} = .59, p = .34, partial η\textsuperscript{2} = .02), but their interaction was significant (F\textsubscript{1,63} = 4.44, p = .04, partial η\textsuperscript{2} = .07). Post hoc comparisons showed that for the Suppression group, reaction times were slower for the High OC group compared to the Low OC group (p = .04). There was no difference between those in the acceptance condition. Follow-up analyses tested the impact of OC group and thought control strategy on reaction times to disgust words specifically, based on Wegner and colleagues (1993) prediction that suppression/acceptance instructions should impact the processing of disgust words. Only a marginal interaction was observed (F\textsubscript{1,67} = 2.91, p = .09, partial η\textsuperscript{2} = .04), such that the suppression instructions caused some interference for the high OC participants (slower RT; p = .05), but had the reverse effect on the low OC participants.

**ERN.** The effects of thought strategy (acceptance/suppression), OC level (high/low) and site (Fz/Cz) on ERN amplitudes for correct and incorrect (ERN) trials were examined using a Mixed Linear Model (MLM). Post-hoc analyses were run using least-squares means differences in R (Lenth, 2016) with a Tukey correction for multiple comparisons. It was hypothesized that high OC and acceptance would be associated with a larger ERN relative to low OC control and suppression respectively. Furthermore, we sought to explore if thought strategies would be differentially moderated by OC level.

Consistent with recommendations by Volpert-Esmond and colleagues (2017), the final model included site (Fz, Cz), Accuracy (Cor, Err), thought control strategy, and OC level (See Table 4 model parameter summary; R\textsuperscript{2} = .64). Given that at least six errors are needed for a reliable ERN (Olvet & Hajcak, 2009), errors from all conditions in Stroop task were combined for ERN analysis. A main effect of site was found (F\textsubscript{1, 173} = 7.13, b = 0.94, t = 2.67, p = .01) suggesting a larger (more negative) ERN amplitude at Fz relative to Cz. There was also a main effect of accuracy, such that ERN amplitude was greater during error trials relative to correct trials (F\textsubscript{1, 173} = 65.53, b = -5.06, t = -6.75, p < .001). Consistent with hypothesis, this main effect can be further qualified by an OC level by accuracy interaction (F\textsubscript{1, 173} = 12.98, b = 2.87, t = 2.81, p = .01). Post hoc analyses revealed a significant accuracy difference for both levels of OC favoring error trials and a significantly larger ERN for those with high OC in error trials relative to low OC (See Figure 2 top panel). Scalp maps of the voltage distribution for difference waveforms are also presented for each condition (Figure 2). The interaction between accuracy and thought strategy was not significant (p = .12).

An ancillary analysis tested for improvements in model fit by adding variables and interactions at different steps. A comparable model was conducted excluding the three-way interaction based on the pattern of findings for reaction time (i.e., adding the interaction did not improve model fit; new R\textsuperscript{2} = .64). The pattern of findings was largely the same with main effects of site and an accuracy x OC level interaction. However, in this model, the interaction between thought control strategy and accuracy was marginally significant, (F\textsubscript{1, 174} = 3.32, b=1.26, t = 1.80, p = .07) with posthoc analyses showing larger ERN amplitudes for error trials relative to
correct trials and a non-significantly larger ERN amplitude for acceptance error trials relative to suppression (See Figure 2 bottom panel)\(^1\).

Figure 3 seeks to address our exploratory aim of looking at whether OC level differentially impacted the relationship between thought suppression strategies

\(^1\)Follow-up analyses where conducted to determine if our findings could be driven by the presence of a population with clinically relevant symptoms. Separate ANOVA models testing the main effect of thought control in the low OC control group \((F_{1,61} = 3.89, p = .05)\) and the high OC group \((F_{1,61} = 2.58, p = .11)\) were ran.
and the ERN by plotting ERN waveforms for the tested interaction between OC level and thought control strategy as well as the scalp maps of the voltage distribution for difference waveforms in each condition. Although this interaction was not statistically significant ($p = .33$), given the exploratory nature of this aim, the relationship was further investigated to assess whether testing thought strategies in samples with clinical symptoms is a promising area of investigation. The figure would suggest the role of thought control strategy had an opposite effect depending on OC level, with suppression being associated with higher ERN for high OC, whereas for individuals with low OC, acceptance led to a higher ERN.

Correlations were calculated between self-reported intrusions and measures during rest period and ERN during correct and error trials at both Fz and Cz during the Stroop task. When Fz and Cz were combined, a larger ERN (more negative) after error trials was marginally associated with more reported intrusions ($r (116) = -0.15$, $p = .09$), but significantly related to lower reported discomfort ($r (116) = 0.21$, $p = .02$). The latter correlation was contrary to expectations, so we divided this by OC level to further explore this relationship. This association was driven by those low in OC ($r (116) = 0.42$, $p < .001$) and was not observed in those high in OC ($r (116) = 0.11$, $p = .42$). Similarly, this association was found in

Figure 3. Response-locked grand average waveforms erroneous (ERN) responses for Stroop task by level of OC symptomatology and Thought Control Strategy. Negative scores are plotted up. Scalp maps display the voltage distribution of the difference wave (ERN-CRN, 50 ms window centered around the largest peak from 0 to 120ms post response window) and are scaled from -0.6 to -8.6 μV.
individuals in the acceptance condition \( r(116) = 0.33, p = .01 \), but not those in the suppression condition \( r(116) = 0.01, p = .94 \). No other significant correlations were observed between ERN amplitude at both correct and error trials and self-reported intrusions, efforts to suppress, level of discomfort, or level of acceptance.

**DISCUSSION**

This study expanded on emerging literature by exploring whether thought control strategies would differentially relate to ERN amplitude in individuals characterized by OC symptoms, commonly associated with suppression efforts, relative to a low OC control.

**Behavioral Effects**

The present study used a modified emotional Stroop task to investigate the impact of watching disgusting stimuli on individuals using different thought control strategies to cope with cognitive intrusions. Overall, the behavioral findings of this study are consistent with meta-analyses suggesting an initial reduction in intrusions but a small rebound effect following suppression instructions (Abramowitz et al., 2001; Magee et al., 2012). The rebound effect was dependent on the level of OC symptoms, with only high OC participants experiencing greater interference during the Stroop task following suppression instructions relative to acceptance. While we also saw this pattern for disgust-related words (a replication of the work of Wegner et al., 1993), the observation among all word types would suggest that the thought control instructions creates a more general response strategy during the task so that high OC participants given suppression instructions experience overall interference. Research suggests that individuals with OCD are more likely to attempt to suppress unwanted thoughts than controls (Amir, Cashman, & Foa, 1997), which, consistent with the slower reaction times observed in the Stroop task, leads to greater interference in functioning (Storch, Abramowitz, & Keeley, 2009). Relatedly, although no significant difference in self-reported discomfort or acceptance with their intrusive thoughts was observed between thought control strategies, a main effect of OC was observed for level of discomfort.

**Electrophysiological Effects**

Consistent with our hypothesis, the findings replicated the anticipated effect of enhanced ERN amplitudes during error trials for individuals with high OC symptoms relative to those in the low OC group (Gehring et al., 2000; Hajcak & Simons, 2002; Olvet & Hajcak, 2008). However, only in our ancillary analysis a marginally significant relationship with accuracy and thought control strategy was observed, such that ERN amplitude was non-significantly greater for the acceptance condition relative to the suppression condition (see Figure 2 bottom panel). Despite the non-significance of this effect, its direction is consistent with recent research suggesting that mindfulness is associated with enhanced ERN (Saun-
ders, Rodrigo, & Inzlicht, 2016; Teper & Inzlicht, 2013) while reduced amplitudes are observed in suppression conditions (Wang & Yang, 2014). When considering why this effect did not achieve significance, multiple factors can be discussed. For instance, given the amount of data lost through processing, limited power could have influenced the ability of the analyses to achieve statistical significance. Furthermore, it is possible that our basic “suppression” and “acceptance” instructions were not ideal to be able to capture the effects in other studies, which tested meditators or more clinically relevant meditation instruction, and would be consistent with the null-findings observed by Larson, Steffen, and Primosch (2013). To add support to this possibility, Saunders and colleagues (2016) only found an enhanced ERN in their emotion-based meditation and not their thought-based meditation. This is an important differentiation that is relevant to our findings given that the paradigm used in the present study requested that participants suppress or accept their thoughts in response to the disgust eliciting video.

Another possibility considered to understand the marginal effects of our findings was part of what makes the current study unique: the presence of a population with high levels of OC symptoms. Notably a healthy population was used in all of the reviewed studies investigating mindfulness/suppression and the ERN. To determine if our findings could be driven by the presence of a population with clinically relevant symptoms, follow-up analyses were conducted. They found further support that, when considering only individuals in the healthy low OC control group, suppression was associated with reduced ERN relative to the enhanced amplitudes observed in the acceptance condition. Nonetheless, the effect was marginal in the opposite direction when this model was tested in the high OC group participants.

These follow-up analyses are particularly relevant to the third, exploratory aim of the present study. Although the interaction between OC level and thought control strategy was not significant and therefore there is no conclusive affirmations that can be drawn from the present study, these additional analyses in conjunction with the visual differences in waveforms (Figure 3) suggest that perhaps OC may have a role that was not fully powered to be captured within this study. Specifically, for our control group the effects are congruent with the existing literature yet for those with high OC symptoms opposite effects are observed with the suppression condition evincing enhanced ERN relative to the acceptance condition. When examined across groups, larger ERN amplitudes were associated with more reported intrusions. Thus, while not statistically significant here, our findings encourage further exploration. Future research may consider building on noted limitations of the present investigation.

**Limitations and Future Directions**

First, effect sizes observed were smaller than anticipated suggesting we were likely not adequately powered for detecting interactions; however, the effect sizes reported here provide preliminary guidelines. Second, we did not see greater levels of acceptance in those instructed to utilize acceptance during post-task
period. Although this may also be a result of this study being underpowered, it is likely that the instructions for the acceptance condition were overly simple and not comparable to acceptance and mindfulness strategies that have been found to have a positive impact in clinical populations (e.g., acceptance and commitment therapy (ACT); Hayes et al., 1996; Twohig, Hayes, & Masuda, 2006). Furthermore, though consistent with other paradigms of thought control (Litvin, Kovacs, Hayes, & Brandon, 2012; Kropotov 2018), the instructions provided in our task were brief and participants were not asked to practice the strategies before the experiment. This could also account for the mixed findings in the literature of mindfulness and the ERN, where different effects are observed in skilled meditators relative to untrained participants receiving a general instruction on mediation, a skill that can take years to master.

Another important limitation of the present study is that although a control group existed in the form of the low OC control group, there was no control group without added task to enable the comparison between control strategies and no further instruction. This could help elucidate the natural and differential strategies high OC and low OC individuals may engage in following an emotionally upsetting stimulus, which were not assessed in this study. Alternatively, future studies could benefit from a within study longitudinal design to examine modulations in ERN in response to different control thought strategies in greater detail which would allow for more conclusive findings. Finally, this model of thought control was not tailored to each individual’s specific topics of concern. Whereas a disgust-inducing video is a potent stimulus, it may not have engendered thought suppression processes akin to those seen in daily life. Ideographic thought suppression approaches utilizing stimuli specific to participant’s obsessions and compulsions followed by a conflict or error-monitoring task might provide a better test of these perspectives. Despite these limitations, this study represents an important first step to study the effects of suppression and acceptance on the ERN in a sample characterized by clinically relevant symptoms.

CONCLUSION

This study was the first to integrate the investigation of thought suppression and acceptance using psychophysiological constructs in a sample with different levels of OC symptoms. This is an important contribution to the decades of research on thought suppression and its paradoxical effects, which are believed to play a role in the development and maintenance of diverse psychopathologies (for a review see Magee et al., 2012), and took a first step in adapting research on mindfulness and ERN to account for effects of clinically relevant symptoms. The study replicated and extended prior research examining the role of OC traits on Stroop reaction time and ERN amplitude, as well as that of suppression and ERN (Wang & Yang, 2014). Further, waveforms suggest OC status and thought control strategy may interact to influence psychophysiological responses, and that the present study may have been underpowered to find effects. Our results
contribute to existing theories regarding thought suppression’s role in OC symptomatology and to the call to incorporate physiological variables to explore more in-depth the mechanisms of strategies with clinical benefits. Studies that continue to build upon our preliminary findings can provide further evaluation of the proposed change processes inherent in therapeutic interventions, such as ACT and other acceptance-based therapies, and mechanisms that give rise to symptoms of intrusive cognitions across a spectrum of disorders. This line of future research would be consistent with the RDoC initiative and in part reflective of its ultimate goal: integrate findings in clinical neuroscience into developing more targeted treatments.

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REFERENCES


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