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Moderators and predictors of response to deep transcranial magnetic stimulation for obsessive-compulsive disorder

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ABSTRACT

Deep transcranial magnetic stimulation (dTMS) has emerged as a treatment option for adults with obsessive-compulsive disorder (OCD) who continue to exhibit impairing symptoms following an adequate response to first line interventions. Currently, little is known about the predictors or moderators of dTMS outcome for OCD. This paper examined if several theoretically relevant variables may predict and moderate treatment effects including OCD symptom severity, functional impairment, co-occurring depressive symptoms, age, gender, age of OCD onset, and family history of OCD. As part of a previously reported study, 100 patients received 29 dTMS or sham stimulation treatments over 6 weeks. dTMS was administered using a Magstim Rapid2 TMS (The Magstim Co. Ltd., Whitland, Carmarthenshire, United Kingdom) stimulator equipped with a H shaped coil design, which was specifically designed to stimulate the dorsal mPFC-ACC bilaterally. Findings suggest older participants and those with lower OCD severity and disability respond faster to both dTMS and sham stimulation. dTMS of the dorsal mPFC/ACC appeared to have larger benefits for individuals with greater OCD severity, whereas the difference between treatment arms was minimal in those with lower severity. Implications of these findings for treatment of OCD are discussed.

Obsessive compulsive disorder (OCD) is an impairing psychiatric condition (Huppert et al., 2009; Kugler et al., 2013) affecting 1–2% of the population (Karno et al., 1988; Ruscio et al., 2010). First line interventions include cognitive behavioral therapy with exposure and response prevention (CBT), serotonin reuptake inhibitor medications (SRI), or their combination (McGuire et al., 2015; Olatunji et al., 2013). However, approximately 20% of individuals do not respond to combined treatment, and response rates are even lower using CBT or SRI alone (Öst et al., 2015). Deep transcranial magnetic stimulation (dTMS) has emerged as an option for those who continue to exhibit symptoms following an adequate response to first line interventions (Carmi et al., 2019). dTMS differs from standard TMS through the use of the H-coil (versus a figure- 8 coil), which stimulates more deeply (~2 cm versus 3–5 cm) and larger volumes relative to standard TMS which stimulates a focal, relatively superficial, cortical region directly underlying the coils (Lu and Ueno, 2017).

Building on case series level data (Carmi et al., 2018), a pivotal trial demonstrated superiority of dTMS relative to sham stimulation (Carmi et al., 2019). More specifically, 99 treatment-resistant OCD patients (age 22–68) were randomized to either high-frequency (20Hz) or sham dTMS over six weeks of daily treatment paired with individualized symptom provocation. Reduction in OCD symptoms was significantly greater for the dTMS versus sham arm at post-treatment, and 4-weeks follow-up.

Prediction of treatment effects was not examined in this report nor in any other published accounts of dTMS. Among first line therapies, several variables have emerged as potential predictors of response to CBT or SRIs; poorer outcomes have been associated with longer duration of illness (Keijsers et al., 1994), family history of OCD (Garcia et al., 2010), higher OCD and depression severity (Abramowitz and Foa, 2000; Ackerman et al., 1998; Alarcon et al., 1993; de Haan et al., 1997; Denys et al., 2003; Hohagen et al., 1998; Keijsers et al., 1994; Mataix-Cols et al., 1999, 2002; Stein et al., 2001; Steketee et al., 1999, 2001), presence of hoarding (Abramowitz et al., 2003; Black et al., 1998; Mataix-Cols et al., 1999, 2002; Saxena et al., 2002), functional impairment (Huppert et al., 2009; Storch et al., 2014), older age (Olatunji et al., 2013), and female gender (Maher et al., 2010; Raffin et al., 2009).

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However, research on outcome predictors in CBT and SRI are inconsistent.

Potential predictive variables were not examined in Carmi et al. (2019) which was the purpose of the present report. Specifically, we examined if several theoretically relevant variables may predict and moderate treatment effects including obsessive-compulsive symptom severity, functional impairment, co-occurring depressive symptoms, age, gender, age of OCD onset, and family history of OCD. Based on our review of the CBT and SSRI literature, we hypothesized that older age (Olatunji et al., 2013), higher baseline depressive symptoms (Abramowitz and Foa, 2000), higher OCD severity (Ackerman et al., 1998; Alarcon et al., 1993; de Haan et al., 1997; Denys et al., 2003; Hohagen et al., 1998; Keijsers et al., 1994; Mataix-Cols et al., 1999, 2002; Stein et al., 2001; Steketee et al., 1999, 2001), greater functional impairment (Huppert et al., 2009; Storch et al., 2014), earlier age of onset, hoarding symptoms (Abramowitz et al., 2003; Black et al., 1998; Mataix-Cols et al., 1999, 2002; Saxena et al., 2002), and a family history of OCD (Garcia et al., 2010) would be significant moderators of treatment outcome predicting response in TMS but not sham condition.

1. Method

1.1. Participants

A total of 100 adults ages 22–68 years with primary OCD participated in a randomized, sham-controlled study of dTMS relative to sham (Carmi et al., 2019). Additional eligibility criteria included: Y-BOCS score ≥20 and stable on any medications for two months prior to study entry (if applicable). Exclusion criteria included non-OCD primary disorder, severe neurological impairment, and increased risk of seizures. See Carmi et al. (2019) for full description of study sample and procedures.

1.2. Procedures

All subjects provided written informed consent. Briefly, the present study involved a prospective, double-blind, placebo sham-controlled, randomized clinical trial across 11 sites with recruitment occurring between October 2014 and February 2017. After a 3-week screening phase, participants received 6 weeks of treatment/sham, followed by a 4-weeks follow-up phase.

1.3. Deep TMS and sham intervention

Each subject received 29 treatments over 6 weeks (5 treatments/week for weeks 1–5, 4 during the 6th week). dTMS was administered using a Magstim Rapid2 TMS (The Magstim Co. Ltd., Whitland, Carmarthenshire, United Kingdom) stimulator equipped with a H shaped coil design (Roth et al., 2002, 2007; Roth and Zangen, 2014), which was specifically designed to stimulate the dorsal mPFC-ACC bilaterally. The real treatment group received 20 Hz dTMS at 100% of RMT, with 2 s pulse trains and 20 s inter-train intervals (total of 50 trains and 2000 pulses per session). The sham control group received sham (placebo) treatment with identical parameters inducing scalp sensations and instructions about potential side effects. Both groups received a 3–5 min of individualized symptom provocation before each treatment.

1.4. Personalized symptoms provocation

Following previous studies (Carmi et al., 2018; Dinur-Klein et al., 2014; Isserles et al., 2013; Zohar et al., 1988), a 3–5 min individualized symptom provocation was performed before each treatment to activate the relevant neuronal pathways (Tendler et al., 2019). A clinician developed a personalized list of obsessive-compulsive symptom provocations during the first assessment meeting, based on the patient's primary obsessive-compulsive symptoms. Provocations were designed to elicit a moderate level of distress (i.e., rating between 4 and 7 on a 1 to 10 visual analog scale (VAS)). The following represents an exemplar provocation for an individual with unwanted and distress fears of impulsively harming a child: "Are you sure that you didn't harm a child over this last week, but that you just can't remember it, because you weren't paying enough attention? Isn't it possible this is exactly what happened?" The tailored provocation was administrated prior to each treatment session and lasted between 3 and 5 min. In order to maintain the obsessive-compulsive arousal, the patient was reminded about the provocation during the treatment.

1.5. Assessments

Ratings were conducted by trained, blinded independent evaluators. Obsessive-compulsive severity was measured with the Y-BOCS (Goodman et al., 1989), which is a widely-used clinician-administered instrument with sound psychometric properties (Grabill et al., 2008). The Symptom Checklist was used to assess dimensionality using factorially derived scores including symptoms in the following categories: contamination, aggressive, sexual/religious, symmetry, and hoarding (Gallant et al., 2008; Storch et al., 2008). Depressive severity was assessed with the Hamilton Depression Rating Scale (HDRS-21; Hamilton, 1960), which is a widely-used clinician-rating scale of depressive symptoms across 21 items. Functional impairment was assessed via the Sheehan Disability Scale (SDS; Sheehan et al., 1996), which is a self-report 3-item scale capturing impairment due to OCD in work/-school, social, and family life/home domains.

1.6. Analysis plan

As was done in the original trial, analyses were conducted on a modified intent-to-treat sample of 94 patients, as 6 of the randomized patients either dropped out prior to randomization ($n = 1$) or were found after randomization to be ineligible to participate (n = 5, e.g., changed medication during treatment; Carmi et al., 2019). Predictors and moderators were evaluated using multilevel modeling (MLM; Singer et al., 2003). Compared with traditional methods, MLM has been recommended for longitudinal research due to its ability to evaluate trajectories of change, rather than mean differences, account for unequal time points in data (as was done in this study, with assessments taken at baseline and weeks 1, 2, 3, 4, 6, and 10 [4-week posttreatment follow-up]), as well as its ability to assess both fixed and random effects. Missing data were estimated using a full-information maximum likelihood approach.

Predictors were analyzed by testing the effect of the time*predictor interaction on Y-BOCS scores. This analysis provided a test of whether a variable significantly predicts the rate of change in Y-BOCS scores, regardless of sham vs. active treatment. Moderators investigate whether symptom reduction is associated with a variable in one condition but not the other. This was evaluated by analyzing the time*moderator variable*treatment type (active vs. sham dTMS) interaction on Y-BOCS scores. The residual error term produced by partialing out the time*level 2 variable and treatment type effects on their three-way interaction was used to minimize multicollinearity (Lance, 1988). The following variables were tested as predictors and moderators of treatment outcome: age, gender, age of OCD onset, family history of OCD, baseline Y-BOCS scores, baseline HDRS scores, and baseline hoarding symptoms. Age-of-onset, gender, and other OCD symptom dimensions were included as exploratory without directional hypotheses. Separate models were run with end points at week 6 (posttreatment) and at week 10 (four-week follow-up), as the original trial showed that symptoms continued to decline at follow-up, suggesting that a linear growth model extending to week 10 would be appropriate (Carmi et al., 2019).

Three subsequent models were tested for this analysis: a null model without any predictors, a linear growth model evaluating the fixed and random effects of time on Y-BOCS, and a model including predictors and

moderators. Improvements in model fit were evaluated by testing significant changes in −2 log likelihood (-2LL) fit indices. Effect sizes were estimated using Cohen's d based on the t coefficients and degrees of freedom associated with each fixed effect (Cohen, 1992).

With a sample size of 94 and an average of 5.4 measurements per participant, this study was considered well-powered to test hypotheses based on recommendations of sample sizes of at least 50 with at least 5 repeated measurements (i.e., in this study, patients/participants; Maas and Hox, 2005).

2. Results

2.1. Sample characteristics

The sample predominantly identified as white (84%), with a slight majority being male (59%). Average age was 39 years old. Most of the sample was classified as having mild or less severe depressive symptoms (83%; Zimmerman et al., 2013). Fifty-seven percent was classified as having moderate-to-severe OCD symptoms at baseline, 35% having moderate, and 7% as having severe (Storch et al., 2015). There were no significant differences on variables of interest between sham and dTMS groups (Carmi et al., 2019). Descriptive information of the sample and on the predictors and moderators tested in this study are presented in Table 1.

2.2. Predictors and moderators of symptom reduction at post-treatment

The linear growth model including the fixed and random effects of time significantly improved on the null model, χ^2 (2) = 136.72, $p < .001$. The next model included all predictors and moderators, and significantly improved model fit compared with the linear growth model, χ^2 (24) = 50.54, $p = .001$. Age, baseline SDS, and baseline Y-BOCS were all significant predictors, such that faster symptom reduction during the trial (regardless of condition) was associated with older age, $d = -0.62$, $p = .005$, lower initial disability, $d = 0.47$, $p = .034$, and lower baseline symptom severity, $d = 0.50$, $p = .023$. Significant residual, intercept and time random effects were also observed ($ps < .01$). The only significant moderator was baseline Y-BOCS, $d = -0.54$, $p = .017$. Effect sizes for each predictor and moderator in the final model are summarized in Table 2.

A median split of baseline Y-BOCS scores was used for interpretation of the significant time*treatment group*baseline Y-BOCS interaction. Among the half of the sample with lower baseline Y-BOCS scores (i.e., 27 or below), those in the dTMS condition were estimated to experience a 6.3 point Y-BOCS reduction, while those in sham experienced a 4.4 point symptom reduction. Among the half of the sample with higher baseline Y-BOCS scores (i.e., at least 28), the difference between treatment groups was relatively larger, with dTMS being associated with a 5.9 point Y-BOCS reduction compared with 2.0 points in the sham condition. Thus, active dTMS appeared to confer a relatively larger benefit for those with greater baseline severity, apparently due to lesser benefit of sham stimulation in those with higher Y-BOCS scores.

2.3. Predictors and moderators of symptom reduction at four-week follow-up

The linear growth model also improved on the null model in the week 10 analysis, or four-week follow-up, χ^2 (2) = 156.88, $p < .001$. The predictor and moderator model did not improve on the linear growth model, χ^2 (24) = 32.72, $p = .11$, as there was only one significant predictor or moderator in this model; baseline severity was the only significant moderator, $d = -0.45$, $p = .042$. Older age continued to predict faster symptom reduction at a trend level, $d = -0.43$, $p = .051$.

Table 1
Sample characteristics.

Male gender N (%)	55 (59%)
Age M (range)	38.8 (22.2–68.0)
Age of onset M (range)	13.1 (4–30)
Positive family history N (%)	53 (56%)
Baseline SDS M (SD)	19.4 (6.1)
Race	
White N (%)	78 (83%)
African American N (%)	4 (4%)
Asian	3 (3%)
Multiracial	2 (2%)
Native American	2 (2%)
South Asian	2 (2%)
Middle Eastern	2 (2%)
Arab	1 (1%)
Ethnicity	
Hispanic N (%)	6 (6%)
Baseline HDRS	
M (SD)	10.5 (5.6)
None N (%)	34 (36%)
Mild N (%)	44 (47%)
Moderate N (%)	15 (16%)
Severe N (%)	1 (1%)
Baseline Y-BOCS	
M (SD)	27.3 (4.0)
Moderate N (%)	33 (35%)
Moderate-Severe N (%)	54 (57%)
Severe N (%)	7 (7%)

Note: HDRS = Hamilton Rating Scale for Depression; SDS = Sheehan Disability Scale; Y-BOCS = Yale-Brown Obsessive-Compulsive Scale. HDRS cutoffs are based on Zimmerman et al. (2013); Y-BOCS severity cutoff are based on Storch et al. (2015).

Table 2
Fixed and random effects of final predictor/moderator models.

	Week 6	Week 10
Fixed effects	*d*	*d*
Intercept	**12.34*****	**12.21*****
Time	**-.60****	-.31
Predictors		
Age	**-.62****	-.43^{+}
Age of onset	-.019	-.018
Gender	-.15	-.18
Family history	.22	.15
Baseline SDS	**.47***	.32
Baseline HDRS	-.04	-.012
Baseline Y-BOCS	**.50***	.20
Contamination symptoms[a]	.23	.31
Aggressive symptoms[a]	-.26	-.25
Sexual/religious symptoms[a]	.026	.042
Symmetry symptoms[a]	-.073	-.097
Hoarding symptoms[a]	.13	-.006
Moderators		
Age*Treatment	.025	.18
Age of onset*Treatment	.20	-.011
Gender*Treatment	.30	.20
Family history*Treatment	.24	.26
Baseline SDS*Treatment	.33	.31
Baseline HDRS*Treatment	.089	-.047
Baseline Y-BOCS*Treatment	**-.54***	**-.46***
Contamination symptoms[a]	.020	-.013
Aggressive symptoms[a]	-.13	.0055
Sexual/religious symptoms[a]	-.21	-.14
Symmetry symptoms[a]	.33	.13
Hoarding symptoms[a]	-.19	-.16
Random effects	*b*	*B*
Residual	**7.73*****	**8.45*****
Intercept	**7.06****	**10.31*****
Time	**0.29****	**0.15****

$^{+}$p = .051 *p < .05, **p < .01, ***p < .001.
Note: HDRS = Hamilton Depression Rating Scale; SDS = Sheehan Disability Scale; Y-BOCS = Yale-Brown Obsessive-Compulsive Scale. Symptom dimensions were evaluated using factor.

Significant residual, intercept, and time random effects were also observed. See Table 2 for a summary of parameters from the final model.

Inspection of the data suggest that there was a substantial effect of dTMS vs. sham for those with more severe symptoms; the half of the sample with higher baseline Y-BOCS scores (i.e., at least 28, roughly corresponding with at least moderate-to-severe symptoms) were estimated to experience a 7.1-point Y-BOCS reduction in dTMS versus a 2.9-point Y-BOCS reduction in sham. For those with lower baseline symptoms (i.e., 27 or below, roughly corresponding to those with moderate OCD severity; Storch et al., 2015), there did not appear to be a substantial difference between active and sham treatment, with those in dTMS estimated to experience a 5.7 point reduction and those in sham experiencing a 4.7 point reduction. To demonstrate this difference statistically, we ran two MLMs including time and time*treatment group as independent variables and Y-BOCS as a dependent variable; one for the half of the sample with lower baseline severity, and the other for the half with higher baseline severity. The effect of treatment on symptom trajectory was medium-to-large and significant in the high baseline Y-BOCS half of the sample, $d = -.67, p = .047$, and was small and non-significant in the lower baseline Y-BOCS half of the sample, $d = -0.28, p = .37$. This suggested a significant benefit of dTMS versus sham among those with more severe symptoms, but not for those with less severe (i.e., moderate or lower) symptoms in this trial. See Fig. 1 for a visual representation of these data.

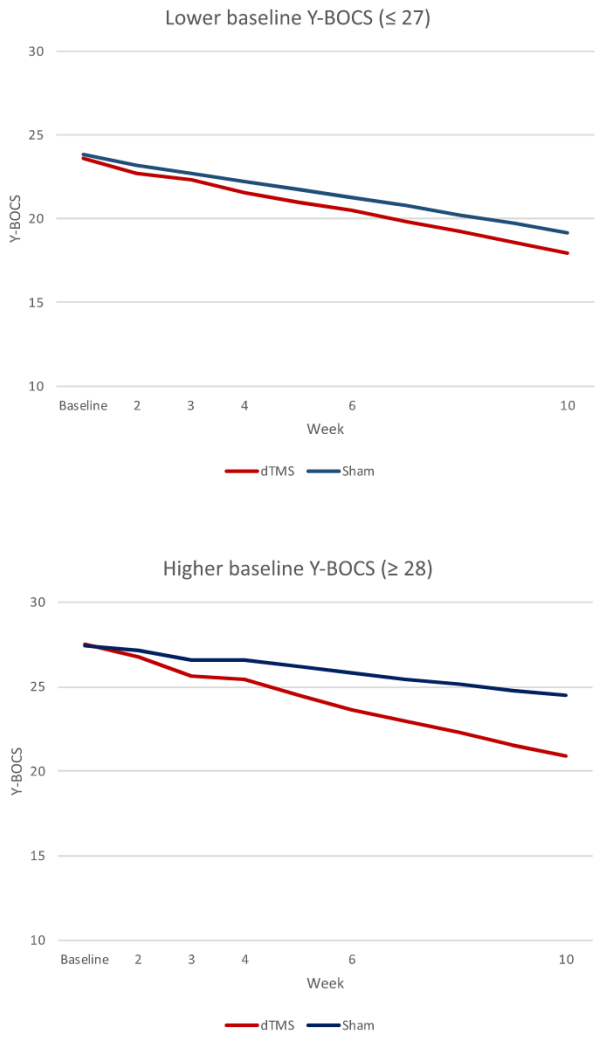

Fig. 1. Treatment Response as a Function of Baseline OCD Severity.

3. Discussion

This study examined predictors and moderators of treatment outcome in a sample of 94 adults with OCD undergoing daily sessions of dTMS of the dorsal mPFC and ACC or sham dTMS over a period of six weeks. Significantly greater reductions in OCD symptoms were observed in the dTMS group relative to the sham group both at post-treatment and at 4-weeks follow-up as reported previously (Carmi et al., 2019). Among the different factors examined, older age, lower baseline OCD severity and lower baseline functional disability significantly predicted greater OCD symptom reduction at post-treatment, regardless of treatment condition. Only age was a significant predictor at 10-week follow-up at a trend level. Most notably, baseline OCD severity moderated treatment outcomes both at post-treatment and follow-up, such that dTMS appeared to have stronger efficacy relative to sham for those with more severe symptoms.

Regardless of treatment condition, baseline OCD severity and related functional disability predicted the magnitude of symptom reduction at post-treatment, such that lower initial severity and disability were associated with faster symptom reduction. This is consistent with previous research in individuals with OCD indicating better outcomes following psychotherapeutic and/or pharmacological interventions in individuals with lower initial clinical severity (Keeley et al., 2008; Knopp et al., 2013; Storch et al., 2006; Turner et al., 2018). It is possible that individuals with more severe forms of OCD need additional treatment to achieve benefits equivalent to those observed in less affected individuals, independent of treatment modality. On the other hand, moderation analyses indicated greater baseline OCD severity was associated with larger symptom improvement at post-treatment and follow-up specifically in the active dTMS group relative to sham. Hence, despite showing slower improvement rates, participants with elevated OCD severity reached larger relative benefits from dTMS versus sham compared to those with lower OCD severity. This could be explained by the fact that there was more room for improvement in the more severe cases suggesting that dTMS appears as a significantly better option relative to Sham for those with severe OCD. Among those with less severe OCD, there was a more pronounced placebo response to sham stimulation compared to those with more severe OCD. Of note, both arms received symptom provocations and attention from compassionate clinicians. It may be that those with more significant symptomology require additional robust treatment to achieve gains. It is important to note that all participants had at least moderate OCD severity and had incomplete response to previous CBT and/or SRI treatments (Carmi et al., 2019). Hence, dTMS of the mPFC/ACC may constitute an effective treatment specifically for moderate-severe to severe, treatment-resistant cases of OCD. The ACC is involved in error monitoring (Brown and Braver, 2005) and detection of cognitive conflicts (van Veen and Carter, 2002), which have been consistently shown to be altered in OCD (Brem et al., 2012). It may be that these alterations are more pronounced in individuals with more severe OCD presentations; therefore, targeting their neural substrates may have a greater impact for this specific OCD subgroup. Conversely, moderate cases may benefit from other approaches that are less invasive than dTMS, but more intensive or comprehensive than standard forms of psychotherapy or pharmacotherapy, such as intensive CBT or a combination of CBT and SRI. It is also possible that dTMS is effective in reducing particularly high OCD levels to a certain threshold from which other forms of treatment may be undertaken. Baseline OCD severity was unrelated to response to rapid TMS of the dorsal mPFC in a previous study (Dunlop et al., 2016). The discrepancy with our findings could be due to methodological differences (e.g. use of a different head coil) and/or to a lack of statistical power in the latter study, which only included 20 adults with OCD.

Regarding other predictors, older age predicted faster symptom reduction from baseline to post-treatment and follow-up, independent of treatment condition. This result was somewhat unexpected as most previous research has failed to reveal significant associations between

age and either SRI (Hazari et al., 2016) or CBT outcomes (Keeley et al., 2008; Olatunji et al., 2013) in adults with OCD. As the association found in the present study was not specific to the active treatment group, it is unlikely to reflect differences at the neural level. Rather, other age-related factors may better explain the links between age and reduction in OCD symptoms. For instance, older age has been associated with greater social desirability (Erskine et al., 2007; Thomsen et al., 2005), which, in turn, has been related to greater self-reported psychological well-being (Hitchcott et al., 2020; Soubelet and Salthouse, 2011; Thomsen et al., 2005).

Contrary to our expectations, treatment outcomes were not related to gender, family history of OCD, age of OCD onset, levels of depression, or hoarding symptoms (although few patients endorsed hoarding on the Y-BOCS). Absence of gender differences in treatment outcomes have been reported for other intervention types including SRI (Hazari et al., 2016), CBT (Steketee et al., 2019; Turner et al., 2018), and deep-brain stimulation (DBS; Alonso et al., 2015), suggesting males and females may respond to OCD treatment in a similar way, independent of the modality. A positive family history of OCD has been related to poorer CBT outcome in children (Garcia et al., 2010), but this association has not consistently been reported in adults and for other types of treatment (Alonso et al., 2015; Hazari et al., 2016; Olatunji et al., 2013; Steketee et al., 2019). Older age of OCD onset has been associated with a positive response to DBS (Alonso et al., 2015), but has not been found to be a reliable predictor/moderator of SRI (Hazari et al., 2016) or CBT outcomes (Keeley et al., 2008; Olatunji et al., 2013). Individuals with early-onset OCD may present with greater abnormalities in the striatum, the region most commonly targeted by DBS for OCD (Alonso et al., 2015). This could explain the greater efficacy of DBS in this subgroup, whereas age of onset may be less determinant of outcomes of stimulation of other brain regions such as the PFC and ACC. Finally, baseline depression levels have been related to post-psychotherapy improvement (Keeley et al., 2008; Steketee et al., 2019; Turner et al., 2018), but do not appear to consistently associate with SRI outcomes (Hazari et al., 2016). The emotional distress experienced by highly depressed individuals may interfere with the cognitive resources necessary to undergo psychotherapy (Keeley et al., 2008), whereas interventions that require less active participation from the patient may be less affected by this factor. Alternatively, the overall low levels of depression among the sample may have prevented us from observing associations with treatment outcomes due to limited variance.

This study has several limitations. First, the sample was mostly White and Non-Hispanic and no information was collected on socioeconomic status (SES), which limits our ability to generalize findings. Second, brain activity in the target brain regions was not recorded; this prevented us from determining the extent to which the mPFC and ACC were stimulated as well as the association of changes in brain activity with the different predictors and moderator of outcome. Finally, some factors significantly associated with outcomes of other treatment forms, such as OCD symptom dimensions and family accommodation (Alonso et al., 2015; Hazari et al., 2016; Turner et al., 2018), were not measured in the current study. Therefore, it is impossible to determine their association with dTMS outcomes. Future studies should include more ethnically diverse samples as well as measures of OCD symptom dimensions and family accommodation. Future work should also include measures of brain activity before and after treatment, to assess potential treatment-related changes and their associations with the different predictors and moderators of outcome.

To our knowledge, this is the first study to investigate the predictors and moderators of response to dTMS of the mPFC/ACC in adults with OCD. Our findings suggest older participants and those with lower OCD severity and disability respond faster to both dTMS and Sham. Importantly, dTMS of the dorsal mPFC/ACC appeared to have larger benefits for individuals with greater OCD severity, whereas the difference between treatment arms was minimal in those with lower severity. This suggests that having a higher minimum Y-BOCS inclusion criterion may best serve to understand actual treatment effects since those with lower OCD severity seem to respond similarly to active and sham interventions. This is also important with regards to treatment selection as it suggest dTMS may be effective for those with particularly high levels of OCD, whereas moderate forms of OCD may benefit from alternative treatments.

Author note

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CRediT authorship contribution statement

Eric A. Storch: Conceptualization, Writing - original draft, Formal analysis, drafted the manuscript, conceptualized the purpose of the manuscript, and supported analyses. He approves of the final content of the paper. **Aron Tendler:** Data curation, Writing - original draft, was involved in data collection, coordinating data collection across multiple sites. He was involved with drafting the paper, critical revision, and approves of the final content of the paper. **Sophie C. Schneider:** Conceptualization, Writing - original draft, Formal analysis, Data curation, helped draft the manuscript, analyze data, and conceptualize the topic. She approves of the final content of the paper. **Andrew G. Guzick:** Conceptualization, Writing - original draft, Formal analysis, Data curation, helped draft the manuscript, analyze data, and conceptualize the topic. He approves of the final content of the paper. **Valerie La Buissonniere-Ariza:** Conceptualization, Writing - original draft, Formal analysis, Data curation, helped draft the manuscript, analyze data, and conceptualize the topic. She approves of the final content of the paper. **Wayne K. Goodman:** Conceptualization, Writing - original draft, helped draft the manuscript, conceptualize the aims, and provide conceptual feedback. She approves of the final content of the paper.

Declaration of competing interest

Dr. Schneider, Dr. Tendler and Dr. Guzick reports no disclosures.

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