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Beyond the Surface: Deep Transcranial Magnetic Stimulation Efficacy in Reducing Craving in Addictive Disorders: A Systematic Review and Meta-Analysis

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ABSTRACT

BACKGROUND: Substance use disorders (SUDs) and gambling disorder (GD) are addictive diseases with a chronic course. Due to the limited efficacy of conventional treatments, there is growing interest in alternative approaches that target the altered neural circuits underlying these disorders. Deep transcranial magnetic stimulation (dTMS) has emerged as a promising neuromodulation technique capable of reaching deep and bilateral brain regions. However, no definite recommendation for its use in addiction treatment exists. In this study, we systematically reviewed and quantitatively analyzed dTMS effects in SUDs and GD.

METHODS: Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, we screened 4 electronic databases up to February 2024 and selected relevant original English-language research articles. Seventeen articles were included in the systematic review and 12 in the meta-analysis. Because only a minority of studies used a sham-controlled design, we ran a main analysis computing the standardized mean change (SMCC) from pre to post real stimulation as the effect size, with self-reported craving scores as the outcome measure.

RESULTS: The results showed a significant and large effect of real dTMS in reducing craving scores (SMCC = −1.26; 95% CI, −1.67 to −0.86; $p < .001$). High heterogeneity across studies was found at both quantitative and qualitative levels.

CONCLUSIONS: Results provide preliminary evidence supporting the effectiveness of dTMS for the treatment of SUDs. Current limitations and future directions are critically discussed, highlighting the need for further rigorous research to refine the therapeutic potential and develop consensus-based guidelines for dTMS clinical application.

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Substance use disorders (SUDs) and gambling disorder (GD) represent major health concerns worldwide, leading to severe maladaptive consequences (1,2) and substantially increasing the global burden of disease (1,3,4). The prevalence of SUDs and GD is alarming: approximately 284 million people worldwide reported drug use in 2020, reflecting a 26% increase since 2010 (5), whereas 2.3 billion adults engaged in gambling over the past year (6).

DSM-5 classifies both SUDs and GD under the category of substance-related and addictive disorders (7). Similarly, the ICD-11 (8) categorizes GD as an addictive disorder, considering the growing evidence of behavioral and neurobiological resemblances between the two conditions. At the behavioral level, for instance, both disorders are characterized by a loss of control over the addictive substance or behavior, which causes severe daily distress. Individuals with addiction typically experience craving, an intense urge to consume the substance of abuse or engage in gambling, which has been traditionally linked to relapses and the maintenance of dependence (9–11). Neurobiologically, addiction is considered a brain disorder characterized by large-scale cortical and subcortical alterations (12,13). Chronic substance intake induces long-term overactivity in the mesolimbic dopamine system (14), which is involved in reward and motivational processes, combined with hypoactivity in the frontostriatal circuit (15,16), which is engaged in self-regulation and decision-making functions. Impairments in these processes may account for the weakened ability of individuals with SUDs to stop seeking the substance of abuse (17,18). Importantly, SUDs and GD share structural and functional abnormalities that partially overlap (19–21).

Although several treatment options are currently available for SUDs and GD (16,21,22), the results remain unsatisfactory (23,24). Therefore, effective alternative or add-on treatment strategies are required. In this context, transcranial magnetic stimulation (TMS) has gained attention as a safe technique for

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reducing addiction-related symptoms, and it has yielded promising, albeit preliminary, results (25–28). Nonetheless, findings from randomized controlled trials (RCTs) have been inconsistent, with some research showing positive outcomes after active versus sham repetitive TMS (rTMS) interventions (29–32), while others have not found differences between the two conditions (33–35). Such heterogeneity highlights the need for further research to clarify which factors influence treatment outcomes.

A key limitation of standard (r)TMS is that figure-of-eight coils only stimulate surface brain regions unilaterally, reaching depths of approximately 2 cm. This constraint prevents the possibility of targeting deeper structures, which are critically involved in addictive disorders. To overcome these limitations, deep TMS (dTMS) has been developed (36). dTMS delivers pulses through the Hesed coil (H-coil), which reaches approximately 4 cm beneath the skull through multiple windings in various planes in the helmet (37–39). Several H-coils have been designed to target different brain networks, thereby expanding dTMS clinical applications across different conditions [for a review, see (39)]. Moreover, a distinguishing feature of H-coils is their ability to deliver simultaneous bilateral stimulation, thus modulating both hemispheres concurrently. Bilateral brain stimulation by H-coils provides a significant clinical advantage in addressing whole-brain disorders, such as addiction, characterized by pathological neural activity that spans widespread neural circuits of both hemispheres (40,41).

Previous systematic reviews and meta-analyses on SUDs and GD including dTMS research suggested promising but preliminary results. However, these studies often included only a small number of dTMS studies (42) or explored dTMS effects together with conventional TMS (43,44) and other noninvasive brain stimulation techniques (43). By focusing exclusively on studies involving dTMS, the current study aims to provide an updated qualitative synthesis and quantitative assessment of dTMS efficacy in treating SUDs and GD.

METHODS AND MATERIALS

Literature Search Strategy and Record Screening

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (45), we conducted a systematic search of 4 databases—PubMed, Scopus, EMBASE, and Web of Science—using a combination of terms related to SUDs, GD, and dTMS for articles published up to February 27, 2024. Articles were included when 1) they were written in English, 2) they involved humans, 3) they were original research, 4) they were published in peer-reviewed scientific journals, 5) they involved patients with SUDs or GD/pathological gambling[a] diagnoses, 6) they involved dTMS, and 7) dTMS was applied for treatment purposes. The screening process was run with Rayyan (https://www.rayyan.ai/) (46). Details on the search strategy and literature screening procedure are provided in the Supplement.

All articles that met the inclusion criteria were added to the systematic review and qualitatively synthesized. Studies that included sufficient data were also quantitatively analyzed in the meta-analysis. The authors used Table 1 to extract relevant information from the studies.

[a]Pathological gambling was the formal diagnosis for GD in DSM-III, DSM-IV, and ICD-10.

Quality Assessment

Quality assessment was conducted for all studies included in the systematic review. Four blinded authors (LDM, GL, GH, and FD) evaluated the studies' quality with assessment tools selected based on the study design. Details on the assessment tools, evaluation procedure, and results are reported in the Supplement.

Quantitative Analysis Procedure

We extracted relevant information from each article, including dTMS protocol features and sample sizes. Since most of the articles included craving assessment, we selected craving measures as the dependent variable for our analyses. Craving means and SDs were collected at baseline, posttreatment, and follow-up. Analyses were run using the metafor package for R (version 3.4.3) (47,48). The primary analysis quantified the impact of real dTMS on craving scores, since this stimulation condition was included in all the studies. The standardized mean change (SMCC) (49) was computed as an effect size, including pretreatment and posttreatment craving scores. Secondary analyses were run on craving scores in 1) a subgroup of studies including a sham condition and 2) a subgroup of studies including follow-up assessments (see the Supplement for statistical analyses and results). For all the analyses, we inserted measures so that negative effect sizes indicate a reduction in craving (i.e., an improvement) compared to baseline. Since some studies included more than one effect size, multilevel random-effects models were tested (50), and if appropriate, they were reported to handle independence violations (51). Heterogeneity was assessed using several measures, including the Q statistic (for sampling error variation), I^2 statistic (for variation not due to sampling error) (52), and prediction intervals (PIs) (the range where a future observation is likely to fall) (53). We used random-effects models to account for heterogeneity due to sampling error and interstudy variance (54). Subgroup and meta-regression analyses were performed when sufficient data were available (55,56). For a detailed description of the statistical procedure and secondary analyses, see the Supplement.

RESULTS

Systematic Review Results

Literature Search. A total of 2326 records were retrieved from the screened databases. Of these, 268 documents were removed as duplicates, and 2058 records were assessed based on their title and abstract, following our eligibility criteria. A total of 1961 documents were excluded, and 97 documents underwent full-text screening. A final sample of 17 articles was considered for qualitative synthesis. The quantitative analysis was run on 12 studies because 5 studies (57–61) did not provide sufficient information to be included in the statistical analysis. See Figure 1 for a graphical representation of the screening procedure.

Table 1. Detailed Information About dTMS Study Protocols

Study	Participants	Coil Type	Stimulation Protocol						Cue Craving Induction Modality	Craving Measures	Follow-Up
			Site	Frequency	Intensity	Duration	Total Pulses	Sessions			
Addolorato *et al.*, 2017 (68)	11 (5 R, 6 S)	H-coil (type not specified)	DLPFC, bilaterally	10 Hz	100%	4 wk (3 ses/wk)	12,000	12	–	OCDS	–
Bolloni *et al.*, 2016 (57)	18 (10 R, 8 S)	H1	Bilateral PFC with preference to the left	10 Hz	100%	4 wk (3 ses/wk)	12,000	12	–	–	3 and 6 months
Ceccanti *et al.*, 2015 (69)	18 (9 R, 9 S)	H-coil (type not specified)	mPFC	20 Hz	120%	2 wk (5 ses/wk)	15,000	10	Sensory and visual	VAS	Monthly assessments for 6 months
Dinur-Klein *et al.*, 2014 (65)	77 (46 R: 14 LF, 32 HF; 31 S)	H4	PFC and insula bilaterally	HF: 10 Hz, LF: 1 Hz	120%	3 wk (5 ses/wk for 2 wk, then 3 ses for 1 wk)	12,870 (HF), 7800 (LF)	13	Visual	sTCQ	6 months telephone interview
Girardi *et al.*, 2015 (58)	10 R	H1	Bilateral PFC with preference to the left	20 Hz	120%	4 wk (5 ses/wk)	44,000	20	–	OCDS	6 months
Harel *et al.*, 2022 (70)	46 (23 R, 23 S)	H7	mPFC and ACC	10 Hz	100%	8 wk (5 ses/wk for 3 wk; 1 ses/wk for 5 wk)	60,000	20	Sensory and visual	PACS	–
Ibrahim *et al.*, 2023 (66)	42 (24 R, 18 S)	H11	Insula bilaterally	10 Hz	120% (110% for individuals with poor tolerability)	4 wk (5 ses/wk)	20,400	20	–	T-QSU	Weekly follow-ups until 8 wk; last follow-up at 6 months
Martinez *et al.*, 2018 (59)	18 (12 R: 6 HF, 6 LF; 6 S)	H7	mPFC, dACC	HF: 10 Hz, LF: 1 Hz	90% on day 1 and then increased to 110% over 2–3 days	3 wk	15,600 (HF), 11,700 (LF)	13	–	Custom VAS	–
Moeller *et al.*, 2022 (60)	20 (10 R,10 S)	H4	PFC and insula bilaterally	10 Hz	100% on day 1, 110% on day 2, 120% on day 3	3 wk (5 ses/wk)	27,000	15	–	–	–
Perini *et al.*, 2020 (71)	45 (23 R, 22 S)	H8	Insula bilaterally	10 Hz	120%	3 wk (5 ses/wk)	22,500	15	Sensory and visual	AUQ, PACS	1, 2, 4, 8, and 12 weeks
Rapinesi *et al.*, 2013 (72)	3 R	H1	Bilateral PFC with preference to the left	20 Hz	120%	4 wk (5 ses/wk)	44,000	20	–	OCDS	6 months
Rapinesi *et al.*, 2015 (73)	23 R	H1	Bilateral PFC with preference to the left	18 Hz	120%	4 wk (5 ses/wk)	39,600	20	–	OCDS	6 months
Rapinesi *et al.*, 2016 (63)	7 R	H1	Bilateral PFC with preference to the left	15 Hz	100%	4 wk (3 ses/wk)	8640	12	–	VAS	1 month
Rapinesi *et al.*, 2018 (61)	82 R	H1	Bilateral PFC with preference to the left	20 Hz	120%	4 wk (5 ses/wk)	44,000	20	–	–	6 months

Table 1. Continued

Study	Participants	Coil Type	Stimulation Protocol					Cue Craving Induction Modality	Craving Measures	Follow-Up
			Site	Frequency	Intensity	Duration	Total Pulses	Sessions		
Rosenberg *et al.*, 2013 (62)	5 R	H1	Bilateral PFC with preference to the left	1 Hz	110%	15 d (1 ses each day)	NR	15	–	SOGS, DAGS, VAS	Families' interviews
Sanna *et al.*, 2019 (64)	47 R (22 HF, 25 iTBS)	H4	PFC and insula bilaterally	HF: 15 Hz, iTBS: 50 Hz	HF: 100%, iTBS: 80%	4 wk (2 ses/d for the first wk, 4 ses/wk over second wk, 3 ses/wk over the third and fourth wk)	48,000 (HF), 12,000 (iTBS)	20	–	CCQ-Brief	–
Zangen *et al.*, 2021 (67)	262 (123 R, 139 S)	H4	PFC and insula bilaterally	10 Hz	120%	6 wk (5 ses/wk for 3 wk plus 1 ses/wk for 3 wk)	32,400	18	Imagery and sensory	TCQ, VAS	3 months

AUQ, Acute Urge Questionnaire; CCQ, Cocaine Craving Questionnaire-Brief; dACC, dorsal anterior cingulate cortex; DAGS, Dannon and Ainhold Gambling Scale; DLPFC, dorsolateral prefrontal cortex; dTMS, deep transcranial magnetic stimulation; HF, high frequency; iTBS, intermittent theta burst stimulation; LF, low frequency; mPFC, medial prefrontal cortex; NR, not reported; OCDS, Obsessive Compulsive Drinking Scale; PACS, Penn Alcohol Craving Scale; R, real dTMS; S, sham stimulation; ses, stimulation session; sTCQ, Short Form of the Tobacco Craving Questionnaire; SOGS, South Oaks Gambling Screen; TCQ, Tobacco Craving Questionnaire; T-QSU, Tiffany Questionnaire of Smoking Urges; VAS, visual analog scale.

Study Details

Participants. Our systematic review included 17 studies comprising 747 patients (males = 486, mean age = 46.7 ± 9.3 years). High between-studies heterogeneity was observed at different levels, including substance-related diagnoses, psychiatric comorbidities, and pharmacological medications. Table 1 details the sample sizes of the studies. A comprehensive description of participants' demographics is provided in Table S5. Substance-related diagnoses included pathological gambling (62), cocaine (57,59,63,64), tobacco (60,65–67), and alcohol (58,61,68–73) use disorders. Psychiatric comorbidities were frequently reported and included dysthymic disorder (58,72), major depressive disorder/episode (61,73), and schizophrenia or schizoaffective disorders (60). In most studies, patients were under a stable pharmacological regimen (58,60–64,66,72,73).

DTMS Protocols and Outcome Measures. DTMS protocols varied across studies (Table 1). Most studies used the H1 coil, bilaterally stimulating the prefrontal cortex (PFC) (57,58,61–63,72,73). Others used the H4 coil, targeting the PFC and insula (60,64,65,67). A few used H8 (71), H7 (59), or H11 (66) coils, stimulating the insula (66,71) or medial PFC, including the anterior cingulate (59). One study (69) targeted the medial PFC without detailing the H-coil type used. Similarly, Addolorato *et al.* (68) targeted the dorsolateral PFC bilaterally without specifying the coil type. In most cases, stimulation sessions included 50 trains per session (range 20–100), with 30 pulses per train (range 30–60) delivered at high frequency (10–20 Hz), while low frequency (1 Hz) was applied in only 3 studies (59,62,65). One study (64) compared dTMS with dTMS intermittent theta burst stimulation. Stimulation intensity ranged from 80% to 120% of the resting motor threshold, with 10 to 20 sessions delivered at varying weekly frequencies, for an overall duration of treatment that ranged from 2 to 8 weeks. Twelve studies incorporated follow-ups with varying timelines. Treatment protocol details are reported in Table S6.

Regarding the outcome measures, craving was evaluated in 14 articles, as assessed by either self-report questionnaires or visual analog scales. One study (61) did not evaluate SUD-related symptoms, Moeller *et al.* (60) used a tobacco self-administration task as the outcome measure, and Bolloni *et al.* (57) used hair analysis to assess treatment efficacy. Five studies (65,67,69–71) administered craving induction before stimulation using different sensory modalities. Several studies included substance consumption objective measures, including urine (64,65,67,68,70), hair (57), and blood (69) tests.

Pre-Post Treatment Craving Scores Meta-Analysis Results

Twelve studies were included in the meta-analysis, but because two of them (64,65) included two groups each, 14 effect sizes were computed. Considering the model selection, the Akaike information criterion (AIC) was lower for the reduced model, thus indicating favorable performance, and the likelihood ratio test (LRT) comparing the two models was not significant (χ^2_1 = 0.70, p = .403). Therefore, we selected the reduced one. The results are summarized in the forest plot

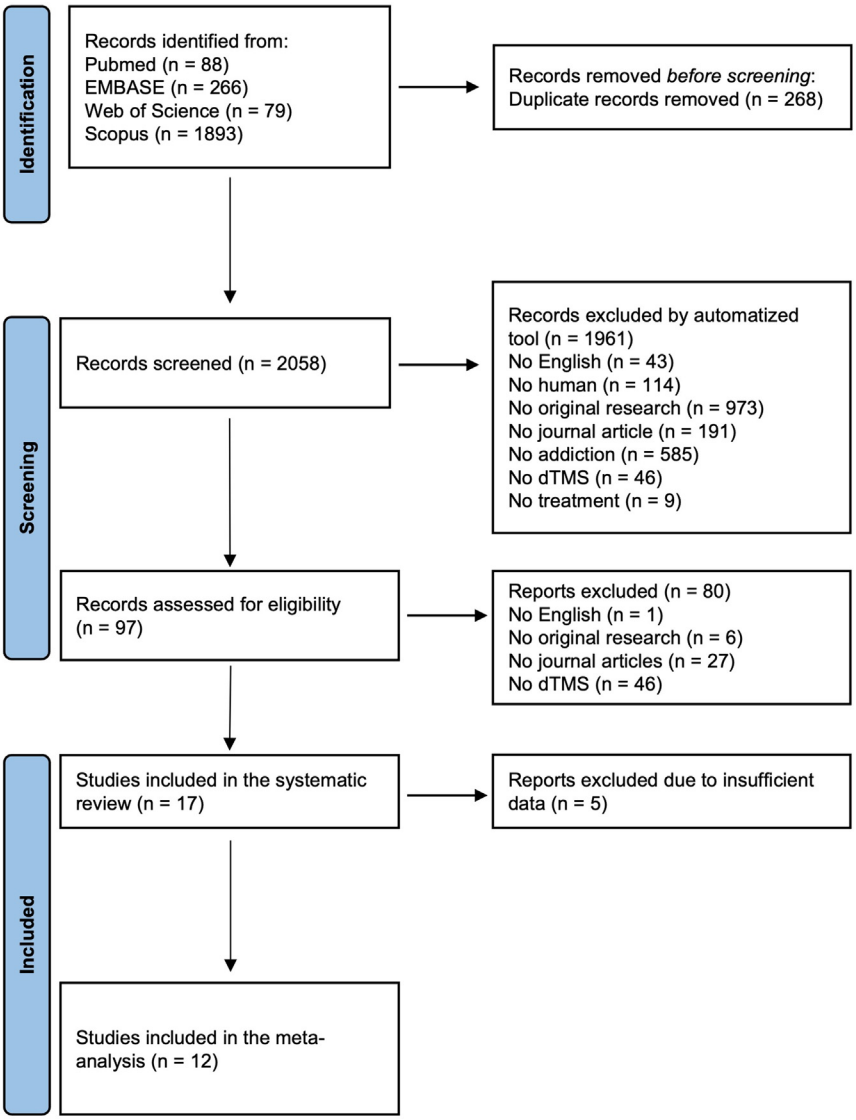

Figure 1. Screening procedure for the selected articles. dTMS, deep transcranial magnetic stimulation.

(Figure 2). The random-effects model showed an effect of the treatment in reducing craving scores (SMCC = −1.26; 95% CI, −1.67 to −0.86), significantly different from zero ($z = -6.17$, $p < .001$). Therefore, the intervention had a large impact on reducing craving[b]. The meta-analysis also revealed high heterogeneity between studies ($Q_{13} = 64.26$, $p < .001$, $\tau^2 = 0.39$ [SE = 0.25]; $I^2 = 79.77\%$ [74.97%–96.98%] [substantial heterogeneity]; PIs, −2.70 to 0.17). The Baujat plot inspection (Figure 3) suggested that the effect sizes 8, 9, and 13 (63,73,64) might be particularly influential, considering their impact on estimated heterogeneity and the pooled effect (74). However, the influence analysis did not highlight influential cases. Publication bias was not explored due to the high heterogeneity. Sensitivity analysis results are reported in the Supplement.

The results of the secondary analysis (see the Supplement for a detailed description of the results) confirmed that the effect of real stimulation remained significant even when the sham/placebo condition was included in the analysis.

Considering the meta-regression analysis, we ran a subgroup analysis to explore possible differences in applying H1 vs. H4 coils. Participants' ages and the number of pulses and sessions were added as continuous predictors. No effects were found for the coil type, patients' age, or number of pulses (*p*s > .435). However, the number of sessions significantly predicted SMCC size ($p < .001$), indicating that craving scores are expected to reduce as the number of sessions increases. See the Supplement for details.

[b]The statistical results remained essentially unchanged when the two effect sizes from Dinur-Klein *et al*. (65) were excluded from the meta-analysis (SMCC = −1.36; 95% CI, −1.82 to −0.90), remaining significantly different from zero ($z = -5.80$, $p < .001$).

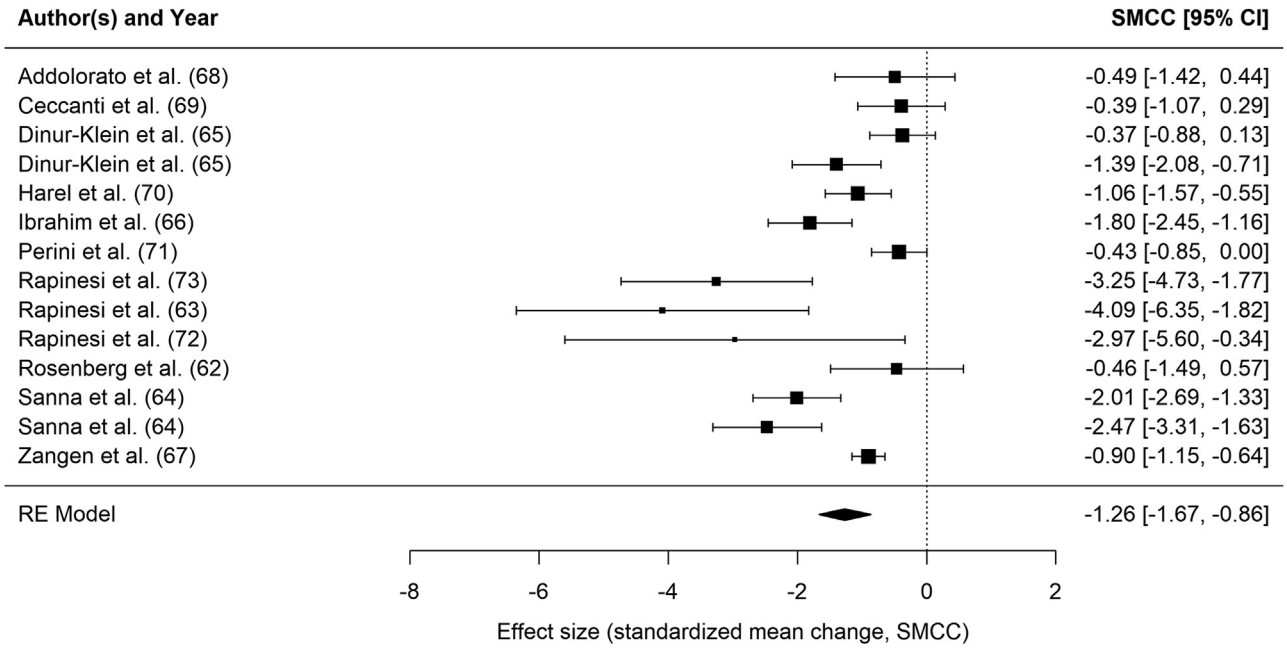

Figure 2. Forest plot summarizing the effect sizes of the deep transcranial magnetic stimulation intervention on craving scores. RE, random effect.

DISCUSSION

In this study, we systematically reviewed and quantitatively analyzed the effectiveness of dTMS in treating addictive disorders. Seventeen original English-language research articles were included in the qualitative synthesis. Pre-post real dTMS effect sizes on craving scores were computed and analyzed in 12 articles, since all included a real stimulation condition. Additionally, since a subset of studies (65–71) included a sham/placebo stimulation, we ran a secondary analysis that included only RCTs.

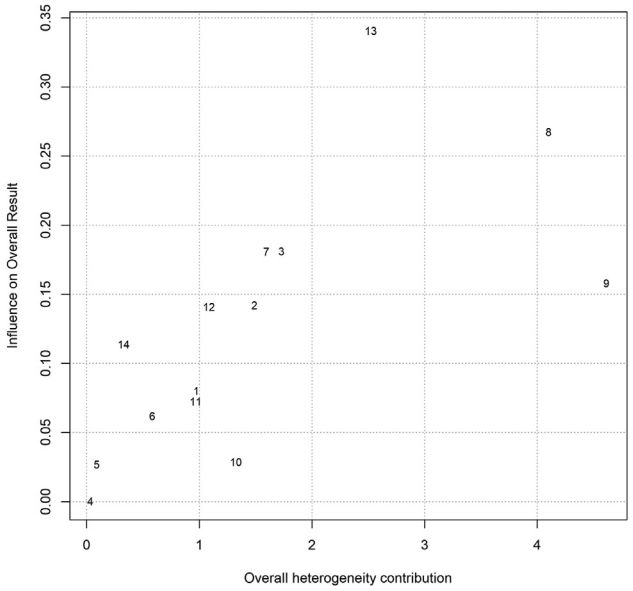

Figure 3. The Baujat plot summarizes the contribution of each study to the meta-analysis heterogeneity, considering pre-post craving scores as the outcome measure. On the x-axis, the overall heterogeneity as measured by Cochran's *Q* test is displayed, whereas on the y-axis, the influence on the pooled effect size is represented. Effect sizes 8, 9, and 13 may be particularly influential considering their impact on estimated heterogeneity and the pooled effect.

Our first quantitative analysis revealed a significant and large effect of dTMS in reducing craving, consistent with previous findings of conventional rTMS (28,42,43,75,76) and dTMS (42–44,77). Although previous efforts have been made to examine the feasibility of dTMS in addiction care, the research has presented some limitations. Metha *et al.* (44) did not distinguish dTMS effect sizes from standard rTMS ones; Zhang *et al.* (42) considered only four dTMS studies; Del Mauro *et al.* (43) analyzed only one dTMS study within noninvasive brain stimulation research; and Kedzior *et al.* (77) assessed only qualitatively dTMS efficacy in treating SUDs. Therefore, to our knowledge, this is the first study to exclusively focus on qualitatively and quantitatively evaluating dTMS effectiveness in targeting craving across SUDs and GD.

Our statistical analysis highlighted high heterogeneity across studies, which was also observed at the qualitative level. Studies differed substantially considering participants' clinical features and stimulation protocols. For instance, participants with SUDs varied regarding the preferred substance of abuse, encompassing cocaine, tobacco, and alcohol. Heterogeneity was also observed at the level of comorbid psychiatric disorders and the allowance of concurrent pharmacological treatment. Stimulation protocols differed in number of sessions, stimulation frequency, intensity, and type of H-coil/stimulated regions. Finally, variability was observed considering the specific tool used to measure craving. We further explored heterogeneity by running a meta-regression

analysis. We did not find differences in effect sizes when using H1 versus H4 coils. However, considering the restricted number of studies included in the analysis (4 and 5 data points, respectively), caution is warranted in interpreting this finding. The continuous predictors of participants' age and number of pulses per session did not influence craving scores. Conversely, the increasing number of sessions predicted a larger reduction in craving. The cumulative effect of stimulation sessions is consistent with previous studies that have applied noninvasive brain stimulation across several disorders, including major depressive disorder (78), depressive symptoms in anxiety disorders (79), and, crucially, SUDs (76). A crucial point of discussion concerns the state of brain activity during dTMS administration. Five studies (65,67,69–71) used a craving induction procedure before dTMS stimulation. The rationale for eliciting craving before stimulation relies on the notion of state dependency of noninvasive brain stimulation, according to which the state (active or resting) of the target networks at the moment of stimulation influences brain activity, functional connectivity, and behavioral response (80–83). Therefore, time-locking noninvasive brain stimulation with cognitive or behavioral interventions by delivering stimulation before, during, or after a task/activity could be beneficial to prime, combine, or consolidate the two intervention effects (84). Moreover, combining brain stimulation with another intervention may offer an additional advantage: it addresses a key concern associated with using brain-based interventions alone, namely the risk that patients may passively rely on the external intervention for their recovery, i.e., they will expect TMS to alleviate craving without engaging in personal effort or behavioral change. According to this perspective, multimodal approaches avoid this risk. Combining stimulation with psychological or psychoeducational intervention can encourage patients to take an active role in their recovery and develop coping strategies to maintain abstinence. Not surprisingly, a higher internal locus of control has been linked to better recovery (85,86). As research in the field advances, dTMS may become an integral part of multimodal treatment strategies for addictive disorders, providing new avenues for managing such complex diseases.

While our results are encouraging, we wish to outline some significant challenges in the framework of dTMS administration for addiction care. First, the limited number of studies included in this work prevents us from drawing any definitive conclusions or making recommendations on the effectiveness of dTMS in treating addictive disorders, highlighting the need for further research in this field. Second, the quality assessment suggested a moderate to high risk of bias for RCTs and a moderate risk of bias for open-label research. Therefore, methodological issues must be cautiously considered in future trial designs. Third, most studies used an open-label design that does not allow for disentangling of the effects of stimulation from placebo effects. This point is particularly relevant because patients with SUDs may exhibit heightened sensitivity to placebo, as shown by sham-controlled rTMS studies on SUDs (34,87–89). To test this hypothesis, we ran a secondary analysis on the subgroup of studies that included a sham-controlled condition. The results revealed a significant small-to-medium effect of real stimulation in reducing craving, confirming the effectiveness of dTMS. However, the limited number of studies in the analysis suggests caution and highlights the need for more sham-controlled studies to corroborate this finding. As a fourth point, studies varied substantially regarding the presence and length of follow-up assessments to track patients' symptomatology after the end of the treatment, which provides information on the sustainability of the therapeutic effects. Despite this variability, we ran an exploratory analysis, including 6 studies that reported data from follow-up assessments in the real stimulation condition, which suggested a large effect of the intervention on craving reduction compared with the baseline scores. Including follow-up measures can be crucial because, in some cases, rTMS effects (namely the difference of real vs. sham stimulation) have emerged only several weeks posttreatment (90–93). Such a finding has been interpreted as a consolidation effect of neurostimulation on long-term neuroplastic change (94).

One crucial point is that craving was included in our analysis because it was the most often reported outcome measure across studies. While craving has traditionally been linked to relapse (10), we acknowledge the limitation of relying solely on this measure. Craving has been proven to be a fluctuating measure (10,95) that varies widely between and within individuals, depending on multiple temporal, contextual, and individual variables, which can affect its reliability (96). Other factors, including emotional dysregulation and impulsive decision making, may drive substance abuse (97–100). Moreover, as a self-report measure, craving is influenced by social desirability and patients' awareness. Thus, craving alone may not fully capture key clinical outcomes, such as functional recovery and consumption behaviors (96), highlighting the need for more objective measures, such as number of relapses and days of abstinence, alongside craving assessment, to better assess the efficacy of interventions. Finally, including only one study that focused on GD highlights the fact that research on this disorder is still in its infancy (21), and further exploration is warranted to shed light on the feasibility and effectiveness of using dTMS to treat GD.

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LDM works as a psychologist at Fondazione Eris ETS, and LJRL is a consultant for Fondazione Eris ETS, which is a nonprofit organization dedicated to addiction rehabilitation through a multidisciplinary approach, including the application of dTMS. All other authors report no biomedical financial interests or potential conflicts of interest.

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REFERENCES

1. Abbott MW (2020): Gambling and gambling-related harm: Recent World Health Organization initiatives. Public Health 184:56–59.

2. Fuster D, Zuluaga P, Muga R (2024): Substance use disorder: Epidemiology, medical consequences and treatment. Med Clin (Barc) 162:431–438.
3. GBD 2019 Risk Factors Collaborators (2020): Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. Lancet 396:1223–1249.
4. Reith G, Wardle H, Gilmore I (2019): Gambling harm: A global problem requiring global solutions. Lancet 394:1212–1214.
5. United Nations Office on Drugs and Crime, Division for Treaty Affairs (2022): World Drug Report 2022. S.l.: United Nations. Available at: https://www.unodc.org/unodc/data-and-analysis/world-drug-report-2022.html. Accessed September 15, 2024.
6. Tran LT, Wardle H, Colledge-Frisby S, Taylor S, Lynch M, Rehm J, *et al.* (2024): The prevalence of gambling and problematic gambling: A systematic review and meta-analysis. Lancet Public Health 9:e594–e613.
7. American Psychiatric Association (2013): Diagnostic and Statistical Manual of Mental Disorders, 5th ed. Arlington, VA: American Psychiatric Association.
8. World Health Organization (2019): International Statistical Classification of Diseases and Related Health Problems, 11th ed. Geneva, Switzerland: World Health Organization.
9. Mallorquí-Bagué N, Mestre-Bach G, Testa G (2023): Craving in gambling disorder: A systematic review. J Behav Addict 12:53–79.
10. Tiffany ST, Wray JM (2012): The clinical significance of drug craving. Ann N Y Acad Sci 1248:1–17.
11. Vafaie N, Kober H (2022): Association of drug cues and craving with drug use and relapse: A systematic review and meta-analysis. JAMA Psychiatry 79:641–650.
12. Dugré JR, Orban P, Potvin S (2023): Disrupted functional connectivity of the brain reward system in substance use problems: A meta-analysis of functional neuroimaging studies. Addict Biol 28: e13257.
13. Tolomeo S, Yu R (2022): Brain network dysfunctions in addiction: A meta-analysis of resting-state functional connectivity. Transl Psychiatry 12:41.
14. Devoto F, Zapparoli L, Spinelli G, Scotti G, Paulesu E (2020): How the harm of drugs and their availability affect brain reactions to drug cues: A meta-analysis of 64 neuroimaging activation studies. Transl Psychiatry 10:429.
15. Goldstein RZ, Volkow ND (2011): Dysfunction of the prefrontal cortex in addiction: Neuroimaging findings and clinical implications. Nat Rev Neurosci 12:652–669.
16. Volkow ND, Blanco C (2023): Substance use disorders: A comprehensive update of classification, epidemiology, neurobiology, clinical aspects, treatment and prevention. World Psychiatry 22:203–229.
17. Lüscher C, Robbins TW, Everitt BJ (2020): The transition to compulsion in addiction. Nat Rev Neurosci 21:247–263.
18. Smith RJ, Laiks LS (2018): Behavioral and neural mechanisms underlying habitual and compulsive drug seeking. Prog Neuropsychopharmacol Biol Psychiatry 87:11–21.
19. Kober H, Lacadie CM, Wexler BE, Malison RT, Sinha R, Potenza MN (2016): Brain activity during cocaine craving and gambling urges: An fMRI study. Neuropsychopharmacology 41:628–637.
20. Potenza MN (2008): Review. The neurobiology of pathological gambling and drug addiction: An overview and new findings. Philos Trans R Soc B Biol Sci 363:3181–3189.
21. Potenza MN, Balodis IM, Derevensky J, Grant JE, Petry NM, Verdejo-Garcia A, Yip SW (2019): Gambling disorder. Nat Rev Dis Primers 5:51.
22. Ribeiro EO, Afonso NH, Morgado P (2021): Non-pharmacological treatment of gambling disorder: A systematic review of randomized controlled trials. BMC Psychiatry 21:105.
23. Aragay N, Jiménez-Murcia S, Granero R, Fernández-Aranda F, Ramos-Grille I, Cardona S, *et al.* (2015): Pathological gambling: Understanding relapses and dropouts. Compr Psychiatry 57:58–64.
24. Kabisa E, Biracyaza E, Habagusenga JD, Umubyeyi A (2021): Determinants and prevalence of relapse among patients with substance use disorders: Case of Icyizere Psychotherapeutic Centre. Subst Abuse Treat Prev Policy 16:13.
25. Gay A, Cabe J, De Chazeron I, Lambert C, Defour M, Bhoowabul V, *et al.* (2022): Repetitive transcranial magnetic stimulation (rTMS) as a promising treatment for craving in stimulant drugs and behavioral addiction: A meta-analysis. J Clin Med 11:624.
26. Harmelech T, Hanlon CA, Tendler A (2023): Transcranial magnetic stimulation as a tool to promote Smoking Cessation and decrease drug and alcohol use. Brain Sci 13:1072.
27. Lefaucheur JP, Aleman A, Baeken C, Benninger DH, Brunelin J, Di Lazzaro V, *et al.* (2020): Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): An update (2014–2018). Clin Neurophysiol 131:474–528.
28. Ma T, Sun Y, Ku Y (2019): Effects of non-invasive brain stimulation on stimulant craving in users of cocaine, amphetamine, or methamphetamine: A systematic review and meta-analysis. Front Neurosci 13:1095.
29. Li X, Song G-F, Yu JN, Ai S-H, Ji Q, Peng Y, *et al.* (2021): Effectiveness and safety of repetitive transcranial magnetic stimulation for the treatment of morphine dependence: A retrospective study. Medicine (Baltimore) 100:e25208.
30. Lolli F, Salimova M, Scarpino M, Lanzo G, Cossu C, Bastianelli M, *et al.* (2021): A randomised, double-blind, sham-controlled study of left prefrontal cortex 15 Hz repetitive transcranial magnetic stimulation in cocaine consumption and craving. PLoS One 16:e0259860.
31. Yuan J, Liu W, Liang Q, Cao X, Lucas MV, Yuan TF (2020): Effect of low-frequency repetitive transcranial magnetic stimulation on impulse inhibition in abstinent patients with methamphetamine addiction: A randomized clinical trial. JAMA Netw Open 3:e200910.
32. Zhang T, Song B, Li Y, Duan R, Gong Z, Jing L, *et al.* (2022): Neurofilament light chain as a biomarker for monitoring the efficacy of transcranial magnetic stimulation on alcohol use disorder. Front Behav Neurosci 16:831901.
33. Hoven M, Schluter RS, Schellekens AF, van Holst RJ, Goudriaan AE (2023): Effects of 10 add-on HF-rTMS treatment sessions on alcohol use and craving among detoxified inpatients with alcohol use disorder: A randomized sham-controlled clinical trial. Addiction 118:71–85.
34. Martinotti G, Pettorruso M, Montemitro C, Spagnolo PA, Acuti Martellucci C, Di Carlo F, *et al.* (2022): Repetitive transcranial magnetic stimulation in treatment-seeking subjects with cocaine use disorder: A randomized, double-blind, sham-controlled trial. Prog Neuropsychopharmacol Biol Psychiatry 116:110513.
35. Raikwar S, Divinakumar KJ, Prakash J, Khan SA, GuruPrakash KV, Batham S (2020): A sham-controlled trial of repetitive transcranial magnetic stimulation over left dorsolateral prefrontal cortex and its effects on craving in patients with alcohol dependence. Ind Psychiatry J 29:245–250.
36. Zangen A, Roth Y, Voller B, Hallett M (2005): Transcranial magnetic stimulation of deep brain regions: Evidence for efficacy of the H-Coil. Clin Neurophysiol 116:775–779.
37. Fiocchi S, Chiaramello E, Luzi L, Ferrulli A, Bonato M, Roth Y, *et al.* (2018): Deep transcranial magnetic stimulation for the addiction treatment: Electric field distribution modeling. IEEE J Electromagn RF Microw Med Biol 2:242–248.
38. Parazzini M, Fiocchi S, Chiaramello E, Roth Y, Zangen A, Ravazzani P (2017): Electric field estimation of deep transcranial magnetic stimulation clinically used for the treatment of neuropsychiatric disorders in anatomical head models. Med Eng Phys 43:30–38.
39. Tendler A, Barnea Ygael N, Roth Y, Zangen A (2016): Deep transcranial magnetic stimulation (dTMS) – Beyond depression. Expert Rev Med Devices 13:987–1000.
40. Diana M (2011): The dopamine hypothesis of drug addiction and its potential therapeutic value. Front Psychiatry 2:64.
41. Diana M, Raij T, Melis M, Nummenmaa A, Leggio L, Bonci A (2017): Rehabilitating the addicted brain with transcranial magnetic stimulation. Nat Rev Neurosci 18:685–693.
42. Zhang JJQ, Fong KNK, Ouyang RG, Siu AMH, Kranz GS (2019): Effects of repetitive transcranial magnetic stimulation (rTMS) on craving

and substance consumption in patients with substance dependence: A systematic review and meta-analysis. Addiction 114:2137–2149.
43. Del Mauro L, Vergallito A, Gattavara G, Juris L, Gallucci A, Vedani A, *et al.* (2023): Betting on non-invasive brain stimulation to treat gambling disorder: A systematic review and meta-analysis. Brain Sci 13:698.
44. Mehta DD, Praecht A, Ward HB, Sanches M, Sorkhou M, Tang VM, *et al.* (2024): A systematic review and meta-analysis of neuromodulation therapies for substance use disorders. Neuropsychopharmacology 49:649–680.
45. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* (2021): The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ 372:n71.
46. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A (2016): Rayyan-A web and mobile app for systematic reviews. Syst Rev 5:210.
47. Viechtbauer W (2010): Conducting Meta-Analyses in R with the metafor Package. J Stat Softw 36:1–48.
48. Viechtbauer W, Cheung MWL (2010): Outlier and influence diagnostics for meta-analysis. Res Synth Methods 1:112–125.
49. Gibbons RD, Hedeker DR, Davis JM (1993): Estimation of effect size from a series of experiments involving paired comparisons. J Educ Stat 18:271–279.
50. Harrer M, Cuijpers P, Furukawa T, Ebert D (2021): Doing meta-analysis with R: A hands-on guide. Chapman & Hall/CRC. Available at: https://www.taylorfrancis.com/books/mono/10.1201/9781003107347/meta-analysis-mathias-harrer-pim-cuijpers-toshi-furukawa-david-ebert. Accessed October 8, 2024.
51. Becker BJ (2020): 17 - Multivariate Meta-analysis. In: Tinsley HEA, Brown SD, curatori. In: Handbook of Applied Multivariate Statistics and Mathematical Modeling. San Diego: Academic Press, 499–525.
52. Higgins JPT, Thompson SG, Deeks JJ, Altman DG (2003): Measuring inconsistency in meta-analyses. BMJ 327:557–560.
53. IntHout J, Ioannidis JPA, Rovers MM, Goeman JJ (2016): Plea for routinely presenting prediction intervals in meta-analysis. BMJ Open 6:e010247.
54. Field AP (2013): Meta-analysis in clinical psychology research. In: Comer JS, Kendall PC, editors. The Oxford Handbook of Research Strategies for Clinical Psychology. New York: Oxford University Press, 317–335.
55. Borenstein M, Hedges LV, Higgins JP, Rothstein HR (2021): Introduction to Meta-analysis. Chichester, UK: John Wiley & Sons.
56. Higgins JP, Green S (2008): Cochrane Handbook for Systematic Reviews of Interventions. Chichester, UK: John Wiley & Sons Ltd.
57. Bolloni C, Panella R, Pedetti M, Frascella AG, Gambelunghe C, Piccoli T, *et al.* (2016): Bilateral transcranial magnetic stimulation of the prefrontal cortex reduces cocaine intake: A pilot study. Front Psychiatry 7:133.
58. Girardi P, Rapinesi C, Chiarotti F, Kotzalidis GD, Piacentino D, Serata D, *et al.* (2015): Add-on deep transcranial magnetic stimulation (dTMS) in patients with dysthymic disorder comorbid with alcohol use disorder: A comparison with standard treatment. World J Biol Psychiatry 16:66–73.
59. Martinez D, Urban N, Grassetti A, Chang D, Hu MC, Zangen A, *et al.* (2018): Transcranial magnetic stimulation of medial prefrontal and cingulate cortices reduces cocaine self-administration: A pilot study. Front Psychiatry 9:80.
60. Moeller SJ, Gil R, Weinstein JJ, Baumvoll T, Wengler K, Fallon N, *et al.* (2022): Deep rTMS of the insula and prefrontal cortex in smokers with schizophrenia: Proof-of-concept study. Schizophrenia (Heidelb) 8:6.
61. Rapinesi C, Kotzalidis GD, Ferracuti S, Girardi N, Zangen A, Sani G, *et al.* (2018): Add-on high frequency deep transcranial magnetic stimulation (dTMS) to bilateral prefrontal cortex in depressive episodes of patients with major depressive disorder, bipolar disorder I, and major depressive with alcohol use disorders. Neurosci Lett 671:128–132.
62. Rosenberg O, Klein LD, Dannon PN (2013): Deep transcranial magnetic stimulation for the treatment of pathological gambling. Psychiatry Res 206:111–113.
63. Rapinesi C, Del Casale A, Di Pietro S, Ferri VR, Piacentino D, Sani G, *et al.* (2016): Add-on high frequency deep transcranial magnetic stimulation (dTMS) to bilateral prefrontal cortex reduces cocaine craving in patients with cocaine use disorder. Neurosci Lett 629:43–47.
64. Sanna A, Fattore L, Badas P, Corona G, Cocco V, Diana M (2019): Intermittent theta burst stimulation of the prefrontal cortex in cocaine use disorder: A pilot study. Front Neurosci 13:765.
65. Dinur-Klein L, Dannon P, Hadar A, Rosenberg O, Roth Y, Kotler M, Zangen A (2014): Smoking Cessation induced by deep repetitive transcranial magnetic stimulation of the prefrontal and insular cortices: A prospective, randomized controlled trial. Biol Psychiatry 76:742–749.
66. Ibrahim C, Tang VM, Blumberger DM, Malik S, Tyndale RF, Trevizol AP, *et al.* (2023): Efficacy of insula deep repetitive transcranial magnetic stimulation combined with varenicline for smoking cessation: A randomized, double-blind, sham controlled trial. Brain Stimul 16:1501–1509.
67. Zangen A, Moshe H, Martinez D, Barnea-Ygael N, Vapnik T, Bystritsky A, *et al.* (2021): Repetitive transcranial magnetic stimulation for smoking cessation: A pivotal multicenter double-blind randomized controlled trial. World Psychiatry 20:397–404.
68. Addolorato G, Antonelli M, Cocciolillo F, Vassallo GA, Tarli C, Sestito L, *et al.* (2017): Deep transcranial magnetic stimulation of the dorsolateral prefrontal cortex in alcohol use disorder patients: Effects on dopamine transporter availability and alcohol intake. Eur Neuropsychopharmacol 27:450–461.
69. Ceccanti M, Inghilleri M, Attilia ML, Raccah R, Fiore M, Zangen A, Ceccanti M (2015): Deep TMS on alcoholics: Effects on cortisolemia and dopamine pathway modulation. A pilot study. Can J Physiol Pharmacol 93:283–290.
70. Harel M, Perini I, Kämpe R, Alyagon U, Shalev H, Besser I, *et al.* (2022): Repetitive transcranial magnetic stimulation in alcohol dependence: A randomized, double-blind, sham-controlled proof-of-concept trial targeting the medial prefrontal and anterior cingulate cortices. Biol Psychiatry 91:1061–1069.
71. Perini I, Kämpe R, Arlestig T, Karlsson H, Löfberg A, Pietrzak M, *et al.* (2020): Repetitive transcranial magnetic stimulation targeting the insular cortex for reduction of heavy drinking in treatment-seeking alcohol-dependent subjects: A randomized controlled trial. Neuropsychopharmacology 45:842–850.
72. Rapinesi C, Kotzalidis GD, Serata D, Del Casale A, Bersani FS, Solfanelli A, *et al.* (2013): Efficacy of add-on deep transcranial magnetic stimulation in comorbid alcohol dependence and dysthymic disorder: Three case reports. Prim Care Companion CNS Disord 15: PCC.12m01438.
73. Rapinesi C, Curto M, Kotzalidis GD, Del Casale A, Serata D, Ferri VR, *et al.* (2015): Antidepressant effectiveness of deep transcranial magnetic stimulation (dTMS) in patients with Major Depressive Disorder (MDD) with or without Alcohol Use Disorders (AUDs): A 6-month, open label, follow-up study. J Affect Disord 174:57–63.
74. Wang N (2023): Conducting meta-analyses of proportions in R. J Behav Data Sci 3:64–126.
75. Maiti R, Mishra BR, Hota D (2017): Effect of high-frequency transcranial magnetic stimulation on craving in substance use disorder: A meta-analysis. J Neuropsychiatry Clin Neurosci 29:160–171.
76. Song S, Zilverstand A, Gui W, Li HJ, Zhou X (2019): Effects of single-session versus multi-session non-invasive brain stimulation on craving and consumption in individuals with drug addiction, eating disorders or obesity: A meta-analysis. Brain Stimulat 12:606–618.
77. Kedzior KK, Gerkensmeier I, Schuchinsky M (2018): Can deep transcranial magnetic stimulation (DTMS) be used to treat substance use disorders (SUD)? A systematic review. BMC Psychiatry 18:137.
78. Hutton TM, Aaronson ST, Carpenter LL, Pages K, Krantz D, Lucas L, *et al.* (2023): Dosing transcranial magnetic stimulation in major depressive disorder: Relations between number of treatment sessions and effectiveness in a large patient registry. Brain Stimul 16:1510–1521.
79. Vergallito A, Gallucci A, Pisoni A, Punzi M, Caselli G, Ruggiero GM, *et al.* (2021): Effectiveness of noninvasive brain stimulation in the

treatment of anxiety disorders: A meta-analysis of sham or behaviour-controlled studies. J Psychiatry Neurosci 46:E592–E614.
80. Isserles M, Shalev AY, Roth Y, Peri T, Kutz I, Zlotnick E, Zangen A (2013): Effectiveness of deep transcranial magnetic stimulation combined with a brief exposure procedure in post-traumatic stress disorder – A pilot study. Brain Stimul 6:377–383.
81. Sack AT, Paneva J, Küthe T, Dijkstra E, Zwienenberg L, Arns M, Schuhmann T (2024): Target engagement and brain state dependence of transcranial magnetic stimulation: Implications for clinical practice. Biol Psychiatry 95:536–544.
82. Vergallito A, Feroldi S, Pisoni A, Romero Lauro LJ (2022): Inter-individual variability in tDCS effects: A narrative review on the contribution of stable, variable, and contextual factors. Brain Sci 12:522.
83. Vergallito A, Varoli E, Pisoni A, Mattavelli G, Del Mauro L, Feroldi S, *et al.* (2023): State-dependent effectiveness of cathodal transcranial direct current stimulation on cortical excitability. NeuroImage 277:120242.
84. Tatti E, Phillips AL, Paciorek R, Romanella SM, Dettore D, Di Lorenzo G, *et al.* (2022): Boosting psychological change: Combining non-invasive brain stimulation with psychotherapy. Neurosci Biobehav Rev 142:104867.
85. Das PR, Talukdar RR, Kumar CJ (2024): Exploring the interplay of abstinence self-efficacy, locus of control, and perceived social support in substance use disorder recovery. Curr Med Res Opin 40:1625–1635.
86. Israel UN, Aroyewun BA, Obi L (2024): Locus of control and impulsivity as correlates of substance use disorder among outpatients in a Psychiatric Hospital. IFE PsychologIA 32:30–39.
87. Addicott MA, Kinney KR, Saldana S, Ip EHS, DeMaioNewton H, Bickel WK, Hanlon CA (2024): A randomized controlled trial of intermittent theta burst stimulation to the medial prefrontal cortex for tobacco use disorder: Clinical efficacy and safety. Drug Alcohol Depend 258:111278.
88. Mikellides G, Michael P, Psalta L, Stefani A, Schuhmann T, Sack AT (2022): Accelerated intermittent theta burst stimulation in Smoking Cessation: Placebo effects equal to active stimulation when using advanced placebo coil technology. Front Psychiatry 13:892075.
89. Mostafavi SA, Khaleghi A, Mohammadi MR (2020): Noninvasive brain stimulation in alcohol craving: A systematic review and meta-analysis. Prog Neuropsychopharmacol Biol Psychiatry 101:109938.
90. Du XD, Li Z, Yuan N, Yin M, Zhao XL, Lv XL, *et al.* (2022): Delayed improvements in visual memory task performance among chronic schizophrenia patients after high-frequency repetitive transcranial magnetic stimulation. World J Psychiatry 12:1169–1182.
91. Freitas C, Fregni F, Pascual-Leone A (2009): Meta-analysis of the effects of repetitive transcranial magnetic stimulation (rTMS) on negative and positive symptoms in schizophrenia. Schizophr Res 108:11–24.
92. Li Z, Yin M, Lyu XL, Zhang LL, Du XD, Hung GCL (2016): Delayed effect of repetitive transcranial magnetic stimulation (rTMS) on negative symptoms of schizophrenia: Findings from a randomized controlled trial. Psychiatry Res 240:333–335.
93. Xiu MH, Guan HY, Zhao JM, Wang KQ, Pan YF, Su XR, *et al.* (2020): Cognitive enhancing effect of high-frequency neuronavigated rTMS in chronic schizophrenia patients with predominant negative symptoms: A double-blind controlled 32-week follow-up study. Schizophr Bull 46:1219–1230.
94. Fitzsimmons SMDD, Oostra E, Postma TS, van der Werf YD, van den Heuvel OA (2024): Repetitive transcranial magnetic stimulation–induced neuroplasticity and the treatment of psychiatric disorders: State of the evidence and future opportunities. Biol Psychiatry 95:592–600.
95. Sayette MA (2016): The role of craving in substance use disorders: Theoretical and methodological issues. Annu Rev Clin Psychol 12:407–433.
96. Moeller SJ, Maloney T, Parvaz MA, Dunning JP, Alia-Klein N, Woicik PA, *et al.* (2009): Enhanced choice for viewing cocaine pictures in cocaine addiction. Biol Psychiatry 66:169–176.
97. Cavicchioli M, Movalli M, Ramella P, Vassena G, Prudenziati F, Maffei C (2020): Feasibility of dialectical behavior therapy skills training as an outpatient program in treating alcohol use disorder: The role of difficulties with emotion regulation and experiential avoidance. Addict Res Theor 28:103–115.
98. Cavicchioli M, Vassena G, Movalli M, Maffei C (2020): Is craving a risk factor for substance use among treatment-seeking individuals with alcohol and other drugs use disorders? A meta-analytic review. Drug Alcohol Depend 212:108002.
99. Gass JC, Motschman CA, Tiffany ST (2014): The relationship between craving and tobacco use behavior in laboratory studies: A meta-analysis. Psychol Addict Behav 28:1162–1176.
100. Stevens L, Verdejo-García A, Goudriaan AE, Roeyers H, Dom G, Vanderplasschen W (2014): Impulsivity as a vulnerability factor for poor addiction treatment outcomes: A review of neurocognitive findings among individuals with substance use disorders. J Subst Abuse Treat 47:58–72.