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Cognition in trichotillomania: a meta-analysis

Aliza Ali[1], Konstantinos Ioannidis[2,3], Jon E. Grant[4] and Samuel R. Chamberlain[2,3]

[1]University of Southampton Faculty of Medicine, Southampton, UK, [2]Department of Psychiatry, University of Southampton, Southampton, UK, [3]Southern Health NHS Foundation Trust, Southampton, UK and [4]Department of Psychiatry, University of Chicago, USA

Review

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Corresponding author:
Aliza Ali;
Email: aa2g19@soton.ac.uk

Abstract

Objective. Trichotillomania (TTM) is a mental health disorder characterized by repetitive urges to pull out one's hair. Cognitive deficits have been reported in people with TTM compared to controls; however, the current literature is sparse and inconclusive about affected domains. We aimed to synthesize research on cognitive functioning in TTM and investigate which cognitive domains are impaired.

Methods. After preregistration on the International Prospective Register of Systematic Reviews (PROSPERO), we conducted a comprehensive literature search for papers examining cognition in people with TTM versus controls using validated tests. A total of 793 papers were screened using preestablished inclusion/exclusion criteria, yielding 15 eligible studies. Random-effects meta-analysis was conducted for 12 cognitive domains.

Results. Meta-analysis demonstrated significant deficits in motor inhibition and extradimensional (ED) shifting in people with TTM versus controls as measured by the stop-signal task (SST) (Hedge's $g = 0.45$, [CI: 0.14, 0.75], $p = .004$) and ED set-shift task ($g = 0.38$, [CI: 0.13, 0.62], $p = .003$), respectively. There were no significant between-group differences in the other cognitive domains tested: verbal learning, intradimensional (ID) shifting, road map spatial ability, pattern recognition, nonverbal memory, executive planning, spatial span length, Stroop inhibition, Wisconsin card sorting, and visuospatial functioning. Findings were not significantly moderated by study quality scores.

Conclusions. Motor inhibition and ED set-shifting appear impaired in TTM. However, a cautious interpretation of results is necessary as samples were relatively small and frequently included comorbidities. Treatment interventions seeking to improve inhibitory control and cognitive flexibility merit exploration for TTM.

Introduction

Trichotillomania (TTM) is a mental health disorder characterized by urges to pull out one's hair, resulting in hair loss. It has a prevalence of approximately 1.7% in adults, appears to be more common in women, and typically presents during early adolescence.[1,2] The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), classifies TTM as an obsessive–compulsive (OC) disorder.

Due to their phenomenological similarities, there is a hypothesized link between obsessive-compulsive disorder (OCD) and TTM. OCD is characterized by rigid, repetitive patterns of cognition and behavior that result in distress and impaired functioning.[3] TTM also involves repetitive behaviors, that is, hair pulling. This, along with other lines of evidence, contributed to its recategorization in the DSM-5 as an OC spectrum disorder, a classification that comprises disorders underpinned by disinhibition of repetitive behaviors.[4] Cognitive deficits, including in inhibitory, flexibility, and planning domains, have been implicated in OC spectrum disorders.[3,5–7] It has been suggested that as an OC spectrum disorder, TTM could also involve deficits in these domains.[8] In particular, cognitive flexibility and inhibition are impaired in OCD so these domains have been hypothesized to demonstrate impaired functioning in TTM accordingly.[9,10]

Existing cognitive research in TTM has yielded inconsistent results. Cognitive flexibility, a domain reliably demonstrating impairment across both OCD and a range of impulse control disorders,[11] is frequently assessed using the Wisconsin Card Sorting Test (WCST) and its computer analog, the intradimensional (ID)/extradimensional (ED) attentional set-shift task. Despite being implicated in OCD with medium–large effect size in meta-analysis,[7] seven studies assessing these tests reported unimpaired cognitive flexibility in TTM patients compared to healthy controls.[4,5,12–15] However, on two other tests of cognitive flexibility, the object alternation task and the Trail Making B Test, TTM patients did demonstrate impaired performance compared to controls.[4,6]

Motor impulsivity also presents inconsistent findings in TTM, yet in OCD, deficits typically occur with medium–large effect sizes in meta-analysis.[16] It is most commonly assessed using the

go/no-go (GNG) test and stop-signal task. One study assessing GNG performance in TTM versus controls reported no significant between-group differences but found that TTM patient performance fell on a scale from fast and inaccurate (impulsive) to slow and accurate (cautious).[10] This suggests that motor inhibitory functioning may vary between individuals with TTM, possibly impaired in some but not others. Further GNG results are inconclusive regarding the presence and/or nature of any motor inhibitory dysfunction in TTM.[17]

The stop-signal task (SST) may be more sensitive to pathologies than the GNG test as it involves inhibition of a motor command that has already been initiated by the brain.[18] Several studies report increased stop-signal reaction times (SSRTs) in TTM patients compared to controls, suggesting impaired motor inhibition.[15,19] Furthermore, relatively impaired performance on the Stroop test of attention inhibition has been reported in TTM.[4] One should, however, note that this test involves several cognitive processes and so is not a precise evaluation of motor inhibition alone. Dysfunctional response inhibition in TTM is also described in the extant literature, which may be underpinned by dysfunctional neuronal activity in circuits associated with motor inhibition, for example, the cortico-striato-thalamo-cortical indirect pathway.[20–22] But again, research findings are inconsistent.

Another cognitive domain implicated in TTM is spatial processing. For example, one review reports that TTM patients performed relatively poorer than controls on the Stylus Maze Test of visuospatial memory.[23,24] Further research has reported impaired performance on two other tests of visual memory, namely the pattern recognition test and the immediate recall Rey–Osterrieth Complex Figure test.[17] Conversely, a separate study found no significant differences between TTM patients' and controls' scores on the Austin Maze task (another visual memory test similar to the Stylus Maze).[12,18] A recent review of the literature on cognition in TTM concluded that the majority of evidence supports the idea that dysfunction in neither visual memory nor verbal memory is associated with TTM.[17] Another aspect of memory, working memory, has also produced inconsistent results. Some studies have reported working memory deficits in TTM, but others have failed to replicate this.[4,10,25,26] This limits the ability to draw conclusions from the current literature.

Other cognitive domains including planning, problem-solving, learning, and decision-making appear to be intact in TTM in the round. For example, cognitive tests that have shown no significant differences between TTM patients and controls include the Tower of London test,[6,25] Rey–Osterrieth Complex Figure test,[4,6,12,13,26] Wechsler Adult Intelligence Scale-Revised (WAIS-R) Block Design Test,[4,6,12] probabilistic learning and reversal test, and the information sampling and Cambridge Gambling tasks.[25] This suggests domain-specific patterns of cognitive dysfunction in TTM.

While the above impressions from considering individual data studies of TTM are valuable, to overcome inconsistencies and pool such findings it is useful to conduct systematic reviews and meta-analyses. While reviews on cognition in TTM exist, they typically have not been preregistered, quantified study quality, and/or conducted meta-analysis. Therefore, the present study aimed to synthesize the current literature on cognition in TTM by conducting a preregistered systematic review and meta-analysis, incorporating methodological quality scores as a moderator. Considering the classification of TTM within the OCD spectrum and the inconsistencies in the extant literature as described above, it was hypothesized that (a) motor inhibition and cognitive flexibility would be impaired in TTM patients compared to healthy controls and (b) there would be no deficits in memory, visuospatial, or verbal abilities in TTM.

Methods

The study was preregistered on the International Prospective Register of Systematic Reviews (PROSPERO) under identity (ID) number CRD42021282295.

Search strategy

Initial scoping searches in the fields of cognition and TTM revealed a minimal number of relevant studies and very limited attempts to synthesize them.

A search strategy encompassing aspects of cognition and cognitive testing in TTM was generated (see Table 1).

The following databases were searched: Ovid MEDLINE® ALL 1946–Oct 2021 via Ovid, Embase Classic+Embase 1947–Oct 2021 via Ovid, and APA PsycINFO via EBSCOhost. Final searches were performed on October 4, 2021. An additional rerun of the search on Ovid MEDLINE, Embase, and PsycINFO was conducted on April 9, 2023, to ensure no more recent work had been omitted. This produced a total of 193 results from Ovid MEDLINE, 298 from Embase, and 302 from PsycINFO. These 793 texts were exported into EndNote X9. Deduplication was performed via both

Table 1. Search Strategy

Set	Search statement	Set	Search statement
1	"cognition".tw.	21	"set–shifting".tw.
2	"cognitive".tw.	22	"intra–dimensional".tw.
3	"neuropsychological test*".tw.	23	"intradimensional".tw.
4	"memory".tw.	24	"extra–dimensional".tw.
5	"executive".tw.	25	"extradimensional".tw.
6	"attention".tw.	26	"inhibition".tw.
7	"decision–making".tw.	27	"stroop".tw.
8	"gambling task".tw.	28	"stop–signal".tw.
9	"Iowa gambling".tw.	29	"go no go".tw.
10	"Bechara gambling".tw.	30	"gng".tw.
11	"Cambridge gamble".tw.	31	"pattern recognition memory".tw.
12	"Cambridge gambling".tw.	32	"information sampling task".tw.
13	"Balloon analogue".tw.	33	"spatial working memory".tw.
14	"N–back".tw.	34	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33
15	"pointing task".tw.	35	"trichotillomania".tw.
16	"tapping".tw.	36	"trich".tw.
17	"tower of London".tw.	37	"hair–pulling disorder".tw.
18	"stockings of Cambridge".tw.	38	"hair pulling".tw.
19	"Wisconsin card".tw.	39	35 OR 36 OR 37 OR 38
20	"ID/ED".tw.	40	34 AND 39

Note:. tw refers to the field tag used to search both title and abstract fields only.

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EndNote's automatic function and manually, yielding 452. These titles were screened for relevancy leaving 291 papers that were subjected to abstract screening using the following criteria:

Inclusion criteria: We included studies that (a) were published between 1946 and the date of search; (b) were written in the English language; (c) examined cognition in patients with diagnosed TTM using valid standard cognitive tasks; and (d) contained enough information to calculate an effect size, that is, mean, standard deviation, and sample size.

Exclusion criteria: We excluded studies that (a) did not report cognitive measures; (b) used nonstandard/non-validated cognitive tasks; (c) lacked a healthy control group; (d) focused on TTM as part of another illness, for example, dementia; and (e) were solely published in the gray literature.

Abstract screening identified 44 relevant studies. These were subjected to a full-text screening also using the above inclusion/exclusion criteria. Three additional papers were identified via citation chaining and screened as described. After full-text screening, 15 papers were eligible for inclusion in the systematic review. Title and abstract screening of the additional search results did not identify any further eligible papers.

The quality scores were defined using the following parameters (one point for each item): TTM diagnosed using a recognized tool, for example, the DSM-5, or any previous iterations; report of comorbidities using a validated instrument (or excluded based on a valid instrument); report and exclusion of substance misuse using an appropriate instrument; report and/or exclusion of impulse control disorders using an appropriate instrument; participant education and/or intelligence quotient (IQ) reported; study reports most appropriate outcome measure; numerical report (mean, standard deviation, and sample size) within paper; controls defined and screened for psychiatric disease; and cognitive tests clearly defined, valid, reliable, and implemented consistently across all participants. Authors AA and SRC performed quality scoring separately and then discussed any non-concordant scoring until an agreement was reached.

Data extraction

Data necessary for meta-analysis (mean of the TTM group and the control group, standard deviation of the TTM group and the control group, and sample size of the TTM group and the control group) were extracted and recorded electronically in a Microsoft Excel spreadsheet. Data required for quality scoring and moderator analysis were also recorded, including the age and gender of the TTM and control groups, geographical location of the participants, TTM diagnostic tool used, and presence/exclusion of comorbidities. The cognitive tests were categorized into cognitive domains, and one best outcome measure was chosen for each by the supervising author. As stated in the original PROSPERO document, only domains with more than three included studies were to be included in the meta-analysis. However, due to a lack of data, this was amended at the data extraction stage to include results from any domain assessed in two or more studies.

Data analysis

Meta-analysis was deemed appropriate given the nature of the identified studies and the similarity of patient groups. A random-effects model was used. RevMan 5.4.1 was used for statistical analysis, and the chosen outcome measure was Hedge's g. RevMan was unable to perform the moderation analyses so these were done using R statistical software's "metafor" package.

All forest plots were formatted with negative x-axis values indicating relatively higher performance in TTM patients compared to controls and positive values indicating relative impairment in TTM patients compared to controls. Q scores and I^2 scores were calculated for each cognitive test as measures of heterogeneity. Author KI performed moderator analyses using study quality scores. Due to the small number of studies included in several of the meta-analyses, moderation analysis was conducted only for domains with over five included studies.

Results

The total number of included studies was 15 in 12 cognitive domains. These domains included motor inhibition, verbal learning, ED shifting, ID shifting, road map spatial ability, pattern recognition, nonverbal memory, executive planning, spatial span length, Stroop inhibition, Wisconsin card sorting, and visuospatial functioning. The average quality score across all included studies was 6.9/9 (76.7%). Full quality scores can be found in Supplementary Table S1.

Figure 1 shows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart detailing the number of studies at each stage of the screening process and the reasons for exclusion. Table 2 provides a summary of the key features of each eligible paper. Meta-analysis results are summarized below; for full forest plots, see the Supplementary Material.

ID shifting: Five datasets measuring ID set-shifting were eligible for inclusion in the meta-analysis. Meta-analysis of 174 patients and 135 controls identified no significant between-group differences (g = 0.02, [CI: −0.21, 0.25], p = .85; Supplementary Figure S1a), with no moderation by quality score (p = .797). There was no evidence of publication bias (p = .59) or significant heterogeneity (chi^2 = 0.93, df = 4 [p = .92], I^2 = 0%).

ED shifting: Meta-analysis of five datasets revealed that TTM is associated with statistically significant impairments on ED set-shifting as compared to healthy controls (g = 0.38, [CI: 0.13, 0.62], p = .003; Supplementary Figure S1b). There was no significant moderation by quality score (p = .084), nor significant heterogeneity (chi^2 = 4.55, df = 4 [p = 0.34], I^2 = 12%).

Stop-Signal Task: Meta-analysis of seven datasets (N = 208 cases, N = 183 controls) showed TTM to be associated with significantly increased SSRTs, indicating impaired motor inhibitory function compared to controls (g = 0.45, [CI: 0.14, 0.75], p = .004; Supplementary Figure S2). There was no moderation by quality score (p = .726). Moderate heterogeneity was demonstrated (chi^2 = 12.38, df = 6 (p = .05), I^2 = 52%), and visual inspection of the forest plot suggested Chamberlain et al.[15] to be an outlier. Exclusion of this study resulted in a model with no significant heterogeneity (chi^2 = 2.71, df = 5 (p = .75), I^2 = 0%). The difference between TTM patients and controls remained significant when this paper was removed (g = 0.33, [CI: 0.12, 0.55], p = .002).

The TTM and control groups did not differ significantly on the following domains and tests: the Stroop test of Stroop inhibition (g = 0.62, [CI: 0.00, 1.23], p = .05); the California Verbal Learning Test (CVLT) of verbal learning (g = −0.04, [CI: −0.41, 0.33], p = .84); the WCST (g = −0.25, [CI: −0.68, 0.18], p = .25); Money's Road Map Test of spatial ability (g = 0.13, [CI: −0.45, 0.72], p = .65); pattern recognition memory (g = 0.19, [CI: −0.23,

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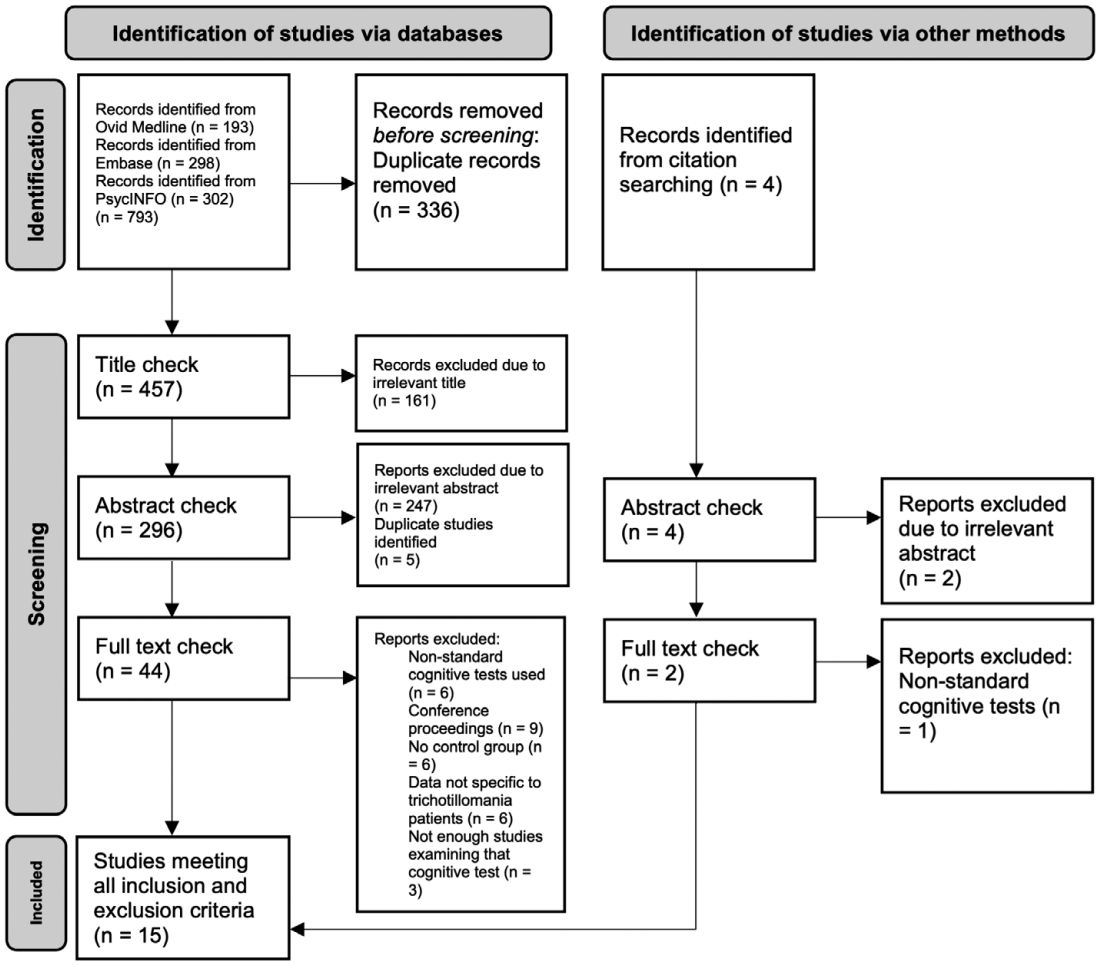

Figure 1. PRISMA flowchart.

0.61], p = .38); the Rey–Osterrieth Complex Figure test of non-verbal memory (g = 0.17, [CI: −0.25, 0.59], p = .43); the Rey–Osterrieth Copy test of visuospatial functioning (g = −0.01, [CI: −0.44, 0.42], p = .97); and the spatial span task of spatial span length (g = 0.40, [CI: −0.03, 0.83], p = .07). There was no significant heterogeneity between the included studies in any of these meta-analyses.

The Tower of London test of executive planning also identified no significant differences between the TTM and control groups (g = 0.04, [CI: −0.44, 0.52], p = .87); however, there was evidence of significant heterogeneity (chi^2 = 7.67, df = 3 (p = .05), I^2 = 61%). Visual inspection of the forest plot showed Wilton et al.[27] to be an outlier. Despite this, reanalysis following the exclusion of this study resulted in broadly similar findings (g = 0.27, [CI: −0.08, 0.62], p = .13, chi^2 = 1.09, df = 2 [p = .58], I^2 = 0%). Therefore, given the small sample size, this study was not excluded from the final analysis. The forest plots for all analyses mentioned above are shown in the Supplementary Figures S3–S11.

Discussion

The main finding of this study is that meta-analysis of the available literature demonstrates that TTM is associated with relatively impaired performance on both the ED shift stage of the ID/ED test and the SST as compared to healthy controls. Concordant with the initial hypotheses, this suggests TTM involves cognitive flexibility and motor inhibition deficits. Also supporting the initial hypothesis, the results indicate that TTM is not associated with deficits in the other cognitive domains that were assessed.

The meta-analysis findings suggest that TTM is associated with impaired motor inhibitory function as measured by the SST. This result was of medium effect size (g = 0.45). However, data were inconsistent at the individual study level: two studies failed to identify significant impairments in TTM patients,[14,27] and one study reported an SST advantage in TTM patients compared to controls.[28] The remaining four described significant inhibitory control deficits in TTM, as demonstrated by poorer SSRTs. It should be noted that two of the studies failing to identify a motor inhibitory deficit in TTM were conducted in children. The authors hypothesized that cognitive deficits may differ between children and adults with TTM, an idea also postulated in another study, which found that significant SSRT impairments were present in adults with later-onset, but not childhood-onset, TTM.[29] Of relevance is that early-onset hair pulling is believed to often resolve without intervention and thus may represent a distinct entity from mainstream TTM, which typically begins in puberty. This may account for the relative lack of such deficits in the studies including early-onset cases.

Additionally, there were some potential sources of error to consider within this analysis. Relevant numerical outcome values were not provided by Odlaug et al.,[19] so estimated values were

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Table 2. Summary of Key Features of Included Studies

Reference	Age	Gender	Comorbidities present	Cognitive task	Cognitive domain	Main findings
Bohne et al., 2005	Adults	Mixed	Yes	California Verbal Learning	Verbal learning	No significant differences between TTM and control groups except on Object Alternation Task*
				Rey–Osterrieth Complex Figure	Nonverbal memory	
				Rey–Osterrieth Copy	Visuospatial functioning	
				Wisconsin card sorting	Wisconsin card sorting	
				Tower of Hanoi (Tower of London)	Executive planning	
Brennan et al., 2016	Children	Mixed	Yes	Stop-signal	Motor inhibition	TTM scored better on stop–signal task than healthy controls (HC) after controlling for age and ADHD
Chamberlain et al., 2006	Adults	Mixed	No	Stop-signal	Motor inhibition	TTM had longer stop–signal reaction times (SSRT) than HC. No difference in the ED shift
				ID/ED	ED shifting	
					ID shifting	
Chamberlain et al., 2007	Adults	Mixed	No	Pattern recognition memory	Pattern recognition	Increased between search errors in TTM on spatial working memory*, no other significant differences
				Tower of London	Executive planning	
Coetzer et al., 1999	Adults	Female	Unclear	Rey–Osterrieth Copy	Visuospatial functioning	Impaired planning and accuracy on Rey–Osterrieth
				Stroop	Stroop inhibition	
Flessner et al., 2016	Children	Mixed	Yes	Stockings of Cambridge (Tower of London)	Executive planning	Differences on ID reversal learning and two stages of Tower of London only
				ID/ED	ID and ED shifting	
				Spatial span	Spatial span length	
Grant et al., 2011	Adults	Mixed	Yes	Stop-signal	Motor inhibition	No significant differences
				ID/ED	ID and ED shifting	
Keuthen et al., 1996	Adults	Female	Unclear	Rey–Osterrieth Complex Figure	Nonverbal memory	Significant differences on Odd Man Out test* and Rey–Osterrieth Complex Figure
Martin et al., 1993	Adults	Mixed	Unclear	Money's Road Map	Road map spatial ability	Increased learning on Rotor Pursuit Task* only
				California Verbal Learning	Verbal learning	
Odlaug et al., 2012	Adults	Mixed	Unclear	Stop-signal	Motor inhibition	Older onset TTM group had impaired SSRT; childhood onset had impaired ED set–shifting
				ID/ED	ID and ED shifting	
Odlaug et al., 2013	Adults	Mixed	Yes	Stop-signal	Motor inhibition	TTM had impaired SSRT and impaired ED set–shifting
				ID/ED	ID and ED shifting	
Odlaug et al., 2014	Adults	Mixed	No	Stop-signal	Motor inhibition	TTM had impaired SSRT
Rettew et al., 1991	Adults	Female	Unclear	Money's Road Map	Road map spatial ability	Significant differences on Stylus Maze Test* only
Stanley et al., 1997	Adults	Mixed	Yes	California Verbal Learning	Verbal learning	Significant differences on every divided attention measure, including Paced Auditory Serial Addition Test*, Trail Making B Test* and WAIS–R arithmetic subscale*, also WAIS–R Digit Symbol subtest* (focused attention)
				Rey–Osterrieth Complex Figure	Nonverbal memory	
				Rey–Osterrieth Copy	Visuospatial functioning	
				Stroop	Stroop inhibition	
				Wisconsin card sorting	Wisconsin card sorting	
Wilton et al., 2020	Children	Mixed	Yes	Pattern recognition memory	Pattern recognition	Faster initial think time on Tower of London
				Stockings of Cambridge (Tower of London)	Executive planning	
				Stop-signal	Motor inhibition	
				Spatial span task	Spatial span length	

*Test not included in meta-analysis.

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derived from a graph. This may have introduced minor numerical inaccuracies. Furthermore, Chamberlain et al.[15] was identified as a source of heterogeneity. This may be due to a number of factors, for example, the sole inclusion of non-medicated TTM patients, while other studies included medicated cases. Also to consider is the potential impact of the varied clinical presentations of TTM. Potentially different types of hair pulling have been described within the literature, for example, pulling that occurs outside of one's awareness, versus that which is preceded by an irresistible urge to pull.[30] Efforts to define valid subtypes of TTM that meaningfully categorize different TTM presentations have as of yet been inconclusive,[31] and any putative effects of clinical variation on cognitive test performance in TTM are therefore undetermined.

Also in support of initial hypothesis (a), the meta-analysis of the ID/ED test revealed significant cognitive flexibility impairments associated with TTM. Both the ID and ED shifting stages were analyzed separately due to their distinct nature. The ID stage examines perceptual flexibility, involving the shifting of attention to novel stimuli within the same dimension (eg, shape). The critical ED stage examines cognitive flexibility. It requires attentional shifts between different perceptual dimensions, inhibiting attention to the dimension that was relevant before and attending to a new one (eg, shape to color). The meta-analysis results indicate that TTM patients show significant impairment in the ED stage, that is, attentional shifting, exclusively, rather than a more general difficulty. ED deficits have been extensively demonstrated in OCD, a function of the cognitive inflexibility associated with OCD symptoms,[32] as well as in autism spectrum disorder where ED reversal errors were found to be positively correlated with a number of repetitive behaviors.[33] It stands to reason that the compulsive behaviors present in TTM may be partly related to such cognitive flexibility deficits, which are quantified by the ED shift stage.

One must also note the complexity of any cognitive flexibility deficits present in TTM. In one included study, only childhood-onset and not later-onset TTM patients demonstrated a significant ED deficit.[29] For this meta-analysis, childhood-onset and later-onset results were pooled using a calculated weighted mean value. Moreover, one study only included children, which potentially increased sample heterogeneity since the cognitive differences between adult and child TTM patients are not known.[34] Both aforementioned studies also used pooled sample data, and it is unclear whether these samples were wholly discrete or included shared participants. It is possible that samples overlapped, resulting in a larger effect size.

The present findings supported the initial hypothesis (b), as meta-analysis failed to identify significant impairments in verbal learning, executive planning, memory, or visual ability associated with TTM. Although this was expected, this hypothesis required investigation due to the paucity of research and specifically meta-analyses of cognition in TTM. This study therefore sought to validate extant findings using meta-analysis, given the nature of its empirical, high-level evidence.

Meta-analysis of CVLT results demonstrated that verbal abilities are not implicated in TTM, in accordance with previous data.

Executive planning was measured by the Tower of London, Tower of Hanoi, and Stockings of Cambridge tests, which were grouped together for the analysis due to their similarity. Despite no overall significant difference between TTM and control groups, one included study reported a significantly increased Mean Initial Think Time 5 Moves[34] and a second found a significantly decreased Mean Initial Think Time 2 Moves[27] compared to controls. Both of these studies examined pediatric samples, while the remaining papers including adults only did not detect any significant between-group differences in any outcome measure. Overall, results indicate that executive planning is not impaired in TTM; however, future research should seek to clarify the nature of any putative distinctions in cognitive performance between child and adult patients.

Visual ability measures included spatial orientation and left–right discrimination, which were examined by Money's Road Map Test. Visuospatial function was investigated by the Rey–Osterrieth Copy test. Neither meta-analysis identified impaired performance in TTM; however, this result must be interpreted cautiously due to the very limited number of eligible datasets.

As hypothesized, meta-analysis demonstrated unimpaired memory performance in TTM on the pattern recognition memory test and the Rey–Osterrieth Complex Figure test. This is consistent with the majority of the extant literature, barring one study that reported performance deficits in TTM on the immediate recall step of the Rey–Osterrieth Complex Figure test of nonverbal memory.[26] This was not replicated by further studies, and the present findings indicate that memory is not likely to be impaired in TTM.

Sufficient datasets examining the Stroop test in TTM were eligible to allow meta-analysis. The Stroop test more broadly examines frontal lobe function, involving several executive functions including attentional inhibition, selective attention, and processing speed.[35] Meta-analysis of Stroop test data revealed a statistically insignificant trend favoring controls. One of the two eligible studies reported TTM-associated impairments in performance; however, comorbidities were not excluded from this sample, with 28% having comorbid generalized anxiety disorder.[4] The study noted a significant correlation between poorer performance on tests of divided attention and increased anxiety levels. While any correlation between anxiety and Stroop performance is not reported, this may have contributed to the large effect size in this study. Again, these findings must be interpreted cautiously given the number of datasets ($n = 2$). The utility of this test in elucidating which cognitive processes are implicated in TTM is also questionable given its non-specificity. Other tests more reliably and precisely measure certain cognitive functions, allowing investigation of their neural underpinnings. Further study of this in TTM populations is required and could contribute to knowledge of the etiology and treatment options for TTM patients.

There are several limitations of the present review. There were a very small number of datasets in some of the domains, for example, pattern recognition ($n = 2$), spatial span length ($n = 2$), road map spatial ability ($n = 2$), Stroop inhibition ($n = 2$), and Wisconsin card sorting ($n = 2$). This may result in inaccuracies due to low power and increased type I and type II error risk. There may also be increased bias and poorer Tau^2 accuracy.

Another potential limitation is the relative lack of diversity of ethnicity and gender within the included samples, which may limit this study's generalizability to wider populations. Future primary research involving larger and more diverse samples could facilitate an improved understanding of cognition in TTM relevant to a population level.

Conclusion

To conclude, it is likely that motor inhibition and cognitive flexibility are impaired in TTM with a medium effect size overall. An important consideration highlighted by this review is the necessity of studies examining pediatric populations and comparing cognition in TTM from childhood to adulthood, ideally following up

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with affected individuals longitudinally. The cognitive variation demonstrated in children with TTM may imply differences in neurocognitive functioning compared to adults or those with later-onset TTM, which may speak to potential heterogeneity within the disorder. Further research on any deficits present in either population could potentially contribute to the literature examining the pathogenesis of TTM in childhood. Also, it is not yet known whether putative adult TTM subtypes differ in terms of cognition, in part due to lack of consensus on whether such subtypes exist, and, if so, how they should be operationalized.

The cognitive findings presented in this paper also call into question the hypothesized relationship between TTM and OCD. The lack of dysfunction in domains implicated in OCD, that is, visuospatial abilities and executive planning, suggests TTM is likely to differ from OCD to some degree in terms of its neurobiology, given the evidence of more generalized cognitive dysfunction in the latter disorder. Future research should seek to clarify the neurobiological nature of the relationship, if any, between the two disorders.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/S1092852924000129.

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