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Effects of tic suppression: Ability to suppress, rebound, negative reinforcement, and habituation to the premonitory urge

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ABSTRACT

The comprehensive behavioral intervention for tics (CBIT) represents a safe, effective non-pharmacological treatment for Tourette's disorder that remains underutilized as a treatment option. Contributing factors include the perceived negative consequences of tic suppression and the lack of a means through which suppression results in symptom improvement. Participants ($n = 12$) included youth ages 10–17 years with moderate-to-marked tic severity and noticeable premonitory urges who met Tourette's or chronic tic disorder criteria. Tic frequency and urge rating data were collected during an alternating sequence of tic freely or reinforced tic suppression periods. Even without specific instructions regarding how to suppress tics, youth experienced a significant, robust (72%), stable reduction in tic frequency under extended periods (40 min) of contingently reinforced tic suppression in contrast to periods of time when tics were ignored. Following periods of prolonged suppression, tic frequency returned to pre-suppression levels. Urge ratings did not show the expected increase during the initial periods of tic suppression, nor a subsequent decline in urge ratings during prolonged, effective tic suppression. Results suggest that environments conducive to tic suppression result in reduced tic frequency without adverse consequences. Additionally, premonitory urges, underrepresented in the literature, may represent an important enduring etiological consideration in the development and maintenance of tic disorders.

Recently, a multi-site, randomized controlled trial found a specific cognitive-behavioral therapy, the comprehensive behavioral intervention for tics (CBIT), to be more effective than psychoeducation and supportive therapy in the treatment of children with tic disorders (Piacentini et al., 2010). Despite its efficacy, CBIT and its predecessor, habit reversal training, remains underutilized (Marcks, Woods, Teng, & Twohig, 2004). The present study focuses on addressing specific barriers to underutilization.

Barriers to widespread acceptance of CBIT as a front-line intervention include clinician, patient, and family fears regarding the perceived negative consequences of tic suppression. Many physicians (55%) believe that tics are not suppressible and a preponderance of health care providers (77%) believe that tic suppression will subsequently result in an increase or 'rebound' in tic frequency (Burd & Kerbeshian, 1987; Marcks et al., 2004; Woods, Conelea, & Himle, 2010). There has also been concern that suppressing a particular tic may worsen other non-targeted tics.

Reduction in total tic severity in the CBIT for children with tic disorders study (Piacentini et al., 2010) suggests that tic suppression, as part of a comprehensive treatment approach, is effective in reducing total tic severity and improving symptoms. An independent line of research has begun to address fears regarding the perceived negative consequences of tic suppression (Himle & Woods, 2005; Meidinger et al., 2005). Single-case behavioral analytic studies suggest that children are capable of suppressing tic symptoms for prolonged periods of time (40 min) when contingently reinforced for effective suppression, even without being provided robust suppression strategies (Woods & Himle, 2004; Woods et al., 2008). Also, there does not appear to be a subsequent increase (rebound) in tic symptoms during post-suppression "tic freely" periods (Himle & Woods, 2005; Meidinger et al., 2005). Lingering concerns regarding the negative effects of tic suppression hinge on the shortcomings associated with single-case studies (i.e., lack of statistical analysis and limited generalizability).

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In addition to concerns about the negative effects of tic suppression, there is a significant question regarding *how* behavioral treatments produce durable decreases in symptom severity (Woods et al., 2011). Genetic and biological contributions and the efficacy of biological interventions are undisputed. However, preliminary evidence suggests that the maintenance and exacerbation of tics as well as tic reduction following non-pharmacological treatment can, in part, be explained via operant conditioning principles. The negative reinforcement hypothesis of tic maintenance suggests that tics persist, in part, because tic completion results in a temporary reduction in the unpleasant "premonitory urge" (i.e., unpleasant feeling or sensation). A single-case study appears to confirm this notion in that premonitory urge ratings were higher during periods of tic suppression and lower during periods of tic completion (Himle, Woods, Conelea, Bauer, & Rice, 2007). The "urge habituation" hypothesis predicts that while tic suppression may initially result in an increase in premonitory urge severity, *continued* tic suppression (a component of CBT for tics) results in an eventual reduction of premonitory urge ratings, thereby breaking the negative reinforcement cycle and resulting in symptom improvement. Indeed, a recent study found that average urge ratings decreased significantly within and between exposure and response prevention treatment sessions for tics (Verdellen et al., 2008).

This current study builds on prior single-case studies by using improved methods, which allow for statistical analysis, and was designed to a) replicate previous findings regarding the ability to suppress tics, b) replicate the absence of a subsequent 'rebound' in tics following prolonged suppression, c) replicate prior findings regarding the negative reinforcement hypothesis with respect to tic maintenance and, d) examine the urge habituation hypothesis in treatment-naive youth with tic disorders. Specific hypotheses were that a) tic frequency would be significantly lower during periods of tic suppression, compared to periods of tic completion, b) there would be no statistical difference in frequency before and after periods of prolonged tic suppression, c) average urge severity ratings would be statistically higher during initial tic suppression than during periods of tic completion, and d) urge severity would return to a statistically non-significant level in comparison to tic completion levels by the end of 40 min of tic suppression.

Method

Participants

Children and adolescents (ages 10–17 years) were recruited at Johns Hopkins University, School of Medicine and the University of Wisconsin-Milwaukee (UWM) via referrals from local clinicians, fliers and bulletin boards, community seminars, and the Tourette Syndrome Association of Greater Washington and Pennsylvania newsletters.

Eligible participants were generally healthy males or females who met the Diagnostic and Statistical Manual of Mental Disorder-Fourth Edition-Text Revision (DSM-IV-TR; APA, 2000) diagnostic criteria for Tourette's disorder or chronic motor or vocal tic disorder (collectively referred to as Chronic Tic Disorders, henceforth). All participants (a) had a primary chronic tic disorder diagnosis, (b) had no history of more than 3 weeks of behavioral treatment for tics or other treatment in which suppression strategies were a primary component, (c) had moderate to severe tic severity determined by a minimum total score of $\geq$14 for both motor and vocal tics or $\geq$10 if motor or vocal tics only on the Yale Global Tic Severity Scale (YGTSS, Leckman et al., 1989), (d) possessed low-average range or better intellectual functioning defined by a two-scale score of $\geq$75 on the Weschler Abbreviated Scale of Intelligence (Psychological Corporation, 1999), (e) reported the presence of a noticeable premonitory urge on the Premonitory Urge for Tic Scale (PUTS, Woods, Piacentini, Himle, & Chang, 2005), (f) were currently exhibiting one or more motor and/or vocal tics at a rate of at least 1 tic per minute. Children with significant Oppositional Defiant Disorder (ODD) or Conduct Disorder symptoms, as determined by the Anxiety Disorders Interview Schedule-Research Lifetime Version (Silverman & Albano, 2002), were excluded from the study. Children with other co-occurring conditions (e.g., obsessive-compulsive disorder [OCD], attention-deficit/hyperactivity disorder [ADHD]) were *not* necessarily excluded provided they met all other eligibility requirements. Pharmacological tic and/or urge suppression would unnecessarily confound results; therefore, potential participants were excluded if they reported on a medication history form a current regimen that included (a) antipsychotics, (b) anti-hypertensives, (c) benzodiazepines, or (d) selective serotonin reuptake inhibitors.

Materials

Tic detector

During all conditions, the child was seated alone in a room facing the *tic detector*, which is an electronic token dispenser housed in a rectangular enclosure with a clear, plastic receptacle attached to the front to gather dispensed tokens. Following the protocol established by Woods and Himle (2004), the child was told that the machine had the ability to monitor and count tics through the web camera mounted on top. The child was also told that when the two lights on the front of the tic detector were illuminated, the detector had started "counting" tics. In reality, two research assistants controlled the tic detector behind a one-way mirror. The rationale for this manipulation was that it allowed researchers to engage in counting tics and rewarding suppression without the child being aware of direct observation, which may have altered tic frequency. This, in turn, allowed for a more accurate and valid assessment of tic frequency. Parents were informed of this manipulation and its purpose during the consent process and were instructed not to inform their child. Immediately following participation in the study, the deception was thoroughly explained and demonstrated to the child. All children signed a debriefing form following the explanation.

Urge thermometer

Using a well-established method (Himle et al., 2007), we measured the premonitory urge by asking participants to provide an overall rating of the urge experience at regular intervals (every 10 s) via the "urge thermometer". Prior to all study conditions, participants were given identical instructions for the urge thermometer. Participants were instructed to state their urge ratings aloud when the urge thermometer appeared. The *urge thermometer* is a rating scale adapted from the "feelings thermometer" for anxiety severity from the Anxiety Disorders Interview Schedule-Research Lifetime Version and was modified to evaluate urge intensity via urge ratings during all conditions (Himle et al., 2007). The scale was presented in an automated fashion at 10-s intervals using identical Microsoft PowerPoint slides displayed on a computer monitor next to the tic detector in the experimental room. Prior research has used longer intervals (30 s) between urge ratings reports to reduce the possibility that movement required to verbally report ratings may result in or disguise tics; however, reporting urge ratings did not appear to reliably elicit or obscure tic symptoms (Himle et al., 2007). In the current study, shorter intervals between urge ratings (10 s) allowed for the collection of ratings during each segment of tic suppression (15 s) and thus more accurate data regarding urge intensity. The scale ranges from 0 to 9, represented by ten ascending bars with corresponding quantitative and qualitative descriptions (i.e., "0" = "not at all" to "9" = "very, very much") indicating the intensity of urges. To ensure participants understanding of the urge thermometer, theoretical urge descriptions were verbally provided for which participants were asked to provide theoretical urge ratings within 3 points of predetermined urge ratings.

Video/audio

Two research assistants were situated behind a one-way mirror in order to count tics, dispense tokens via the tic detector, and videotape the participant discretely. All conditions were recorded via video camera and external microphone. A microphone next to the computer monitor in the experimental room was attached to the video recording equipment in the adjacent room, which enabled urge ratings, as well as vocal tics, to be recorded.

Procedure

Following a brief telephone screen, eligible participants completed all study procedures on two visits.

Visit 1: assessment

During the first visit, participants and their parents provided informed assent and consent and completed (a) the Anxiety Disorders Interview Schedule-Research Lifetime Version (Silverman & Albano, 2002); (b) a demographics, medical history, medication history, and behavioral treatment history form; (c) the YGTSS; (d) the Weschler Abbreviated Scale of Intelligence; (e) the Premonitory Urge for Tics Scale; (f) verbal confirmation from parent and child to establish sufficient tic rate (1 tic per minute). This series of assessments is consistent with the procedures in Himle et al. (2007), and they have been shown to be the best-available diagnostic and evaluation methods for Chronic Tic Disorders and psychological comorbidities in children. These procedures were well tolerated by children and acceptable to their families. Following assessment and preliminary data collection, participants were invited for a second appointment, to occur one week later, to complete the experimental portion of the study.

Visit 2: experimental conditions

In addition to verbal confirmation of tic frequency from parent and child, to ensure the participant exhibited one tic per minute on the day of the study, a 10 min videotaped observation was done as part of the initial experimental condition.

Subjects in the current study participated in an alternating sequence of two conditions and served as their own controls. The two conditions were a 10-min baseline, control, or *tic freely* period and a 40-min differential reinforcement of zero-rate behavior or active *tic suppression* period. The sequence of baseline and differential reinforcement conditions was baseline, differential reinforcement, baseline, differential reinforcement, baseline (total duration = 110 min).

Baseline (BL)

During the three baseline conditions, subjects were asked to sit in front of the tic detector. They were told to make themselves comfortable, to feel free to tic as much or as little as needed, and to ignore the tic detector as much as possible while remaining in their seat. The tic detector did not have any lights on, indicating that it was not counting tics. There were no instructions to suppress and no tokens were delivered during the baseline condition; however, participants were told that they are to state aloud their urge ratings when prompted by the appearance of the urge thermometer on the display screen.

Differential reinforcement of zero-rate behavior (DRO)

During the two differential reinforcement conditions, participants were told to suppress their tics in any way they could without leaving their seat, but they were not told *how* to suppress tic symptoms. As in the baseline condition, participants were told that they would be prompted by the appearance of the urge thermometer to verbally state their urge ratings aloud corresponding to their urge-level at that time. As in Woods and Himle (2004), prior to each differential reinforcement condition, they were also told that tic detector would count tics and dispense tokens, which could be traded in for prizes after the study, for every tic-free period of 15 s. They were also told that following each occurrence of a tic, the timer would restart to determine when the 15 s criteria tic absence had been reached and a token must be dispensed. One research assistant monitored tics through the one-way mirror based on a list of operational definitions of all tics currently displayed by each child. Tic definitions were based on information gathered via the YGTSS and a 10-min videotaped observation as well as a discussion with the patient prior to beginning the experimental conditions. A second research assistant kept the time in the adjacent control room in order to control the tic detector, so the subject was unaware of how much time had elapsed between tics and tokens. As such, the subject was unable to knowingly suppress tics just long enough to receive a token after 15 s. Once one research assistant explained the instructions and left the room the participant was in, the other research assistant simultaneously began the timer, started the urge thermometer, and turned on the tic detector lights that indicated the detector had begun to count tics.

Manipulation checks and accuracy evaluations

Before and after each condition, a manipulation check was conducted to ensure the participants understood the instructions and that they were following the correct procedure. Additionally, after each differential reinforcement condition, the subjects were asked to rate the accuracy of the tic detector in counting their tics. This determination was on a scale from 1 to 5 (1 = "not accurate at all", 2 = "not very accurate", 3 = "somewhat accurate", 4 = "very accurate", and "5 = "extremely accurate").

Data collection

In a manner consistent with previously published papers (Himle et al., 2006), the principal investigator (PI) trained the research assistants to use the list of operational definitions of all tics to score each videotape using the event frequency method. Each videotape was primarily scored for tics per minute (TPM) and tokens dispensed and then scored again for urge ratings. Research assistants scored videotaped observations using the Multi-Option Observation System for Experimental Studies. Tic occurrences were indicated by "M" upon the occurrence of each motor tic and "V" upon the occurrence of each vocal tic. Tokens were indicated by "T". Urge ratings were indicated by digits "0" through "9". Preliminary data from previous studies suggest high within-site inter-observer agreement for the event-frequency method (M = .76, r = .58–.99; Himle et al., 2006).

Quality assurance/inter-rater reliability

Data was collected at Johns Hopkins and the UWM using identical procedures originally developed and utilized by the later. Quality assurance between the two sites was achieved via several plenary teleconferences and post-hoc examination of video-taped sessions 1 and 2 by the PI. Inclusion/exclusion decisions were reached via teleconference with the PI.

To calculate coder accuracy and inter-rater reliability, two research assistants independently scored all participant videotapes.

Inter-rater reliability was calculated using procedures outlined in Himle et al. (2006) and Piacentini, Chang, Walkup, Mink, and Hollenbeck (2006, pp. 227–233). For this calculation, each experimental segment was first divided into 10-s intervals. For each 10-s interval, the number of tics observed by each research assistant was counted and recorded. The lower number of tics reported was divided by the higher number of tics reported, and this number was then multiplied by 100. After this was done for every 10-s interval, the average agreement of the 10-s intervals for each subject was calculated. For subjects that had a low inter-rater reliability (<65%), segments of their videotapes were re-scored, to ensure accurate scoring. To do this, both research assistants watched the tapes that had low agreement together, in order to identify all tics that were present in each subject. Once the tics were agreed upon, the research assistants independently scored any segments that had been identified as having low agreement (<65%). To assure procedural consistency and independent variable integrity, each tape was evaluated for correct implementation of the study protocol and independent variable.

Data analysis

In this within-subjects repeated measures study, the independent variable was condition (baseline or differential reinforcement) and time. The dependent variables were mean tics per minute and average urge ratings (AUR). The mean tics per minute were calculated by dividing the number of tics observed by the duration of the interval sampling period (i.e., mean tics per minute = #/time). The average urge ratings was calculated by dividing the sum of urge ratings for 1 min by the total number of urge ratings provided during that time (average urge ratings = sum of urge ratings/number of urge ratings). Mean tics per minute and average urge ratings were initially calculated for 1 min intervals; however, the data was also collapsed across longer intervals. For instance, if there were no significant differences in mean tics per minute across 10 consecutive 1 min intervals, we calculated mean tics per minute across 10 min (i.e., mean tics per minute = #/10 min). Likewise, if we found no significant differences in mean tics per minute across the two 40-min differential reinforcement conditions, we calculated mean tics per minute across 80 min (i.e., tics per minute = #/80). One-Way Repeated Measures Within Subjects ANOVA was used to examine the hypothesis regarding mean tics per minute and average urge ratings.

Results

Participants

Fifteen participants were enrolled in the study. One participant who passed the initial screen at Johns Hopkins was subsequently determined to be ineligible due to mean tics per minute being less than 1 per minute. Another participant did not complete all baseline and differential reinforcement conditions due to an equipment malfunction at Johns Hopkins. Finally, one participant yielded unusable data due to an equipment malfunction at the University of Wisconsin-Milwaukee.

Demographics and clinical characteristics

Twelve ($n = 12$) youth ages 10–17 years ($M = 13.77$ years, $SD = 2.25$, $Median = 13.91$) ultimately completed and tolerated all study procedures and are used in all subsequent analyses. Participants were mostly upper-middle class Caucasian (83%) males (ratio 11:1) with average intelligence (Weschler Abbreviated Scale of Intelligence $M = 109.25$, $SD = 10.28$) who met DSM-IV-TR Tourette's Disorder criteria (91%). Participants reported moderate-to-marked (Leckman et al., 1989) tic severity (YGTSS Total Tic Score $M = 27.67$, $SD = 8.78$; Total Score $M = 55.00$, $SD = 14.28$), with tics occurring at a rate in excess of 1/minute and with noticeable premonitory urges (PUTS Total Score $M = 24.67$, $SD = 4.82$). Common co-occurring psychiatric conditions included ADHD (18%), OCD (18%), and specific phobia (18%). Less common diagnoses included ODD (8%), social anxiety disorder (8%), separation anxiety disorder (8%), enuresis (8%), and learning disability (8%). One of the two children who met DSM-IV-TR criteria for ADHD was adhering to an active medication regimen, which included a psychostimulant. No participant had previously received behavioral treatment in which tic suppression was a component.

Quality assurance

Visits 1 and 2 occurred approximately 12 days apart ($M = 11.60$, $SD = 9.35$, range = 0–30). All participant ratings regarding the accuracy of the tic detector ranged from 3 to 5, with 20% rating the tic detector as somewhat accurate, 40% as very accurate, and 40% as extremely accurate. With respect to inter-rater reliability, the average agreement across these 12 subjects was calculated ($M = 78\%$, range = 65–90%).

Ability to suppress tics and rebound

Using a One-Way Repeated Measures Within Subjects ANOVA to examine changes in mean tics per minute with-in the three baseline and two differential reinforcement conditions across time (ten consecutive 1-min intervals), we found no significant differences. Fig. 1 depicts data in 1 min sampling intervals; however the following analyses were conducted with collapsed 10 min sampling intervals. There were no significant differences in mean tics per minute (10 min sampling intervals) across the three baseline conditions: baseline 1 ($M = 15.80$, $SD = 10.24$), baseline 2 ($M = 11.61$, $SD = 8.86$), baseline 3 ($M = 13.90$, $SD = 12.24$), $F(1, 11) = 2.18$, *ns* (see Fig. 1). There were also no significant differences in tics per minute (10 min sampling intervals) across the two differential reinforcement conditions: DRO1 0–10 min ($M = 3.93$, $SD = 3.88$), DRO1 11–20 min ($M = 2.82$, $SD = 1.67$), DRO1 21–30 min ($M = 2.92$, $SD = 2.64$), DRO1 31–40 min ($M = 3.28$, $SD = 3.30$) and DRO2 0–10 min ($M = 2.48$, $SD = 2.11$), DRO2 11–20 min ($M = 2.79$, $SD = 3.00$), DRO2 21–30 min ($M = 2.58$, $SD = 2.02$), DRO2 31–40 min ($M = 2.42$, $SD = 2.27$), $F(1, 11) = 2.08$, *ns*. There was a significant difference in mean tics per minute when contrasting the aggregate (30 min) baseline ($M = 13.82$, $SD = 9.71$) and (80 min) differential reinforcement ($M = 2.90$, $SD = 2.45$) conditions, $F(1, 11) = 16.60$, $p < 0.01$ (see Fig. 2).

Negative reinforcement and urge habituation hypothesis

Using a One-Way Repeated Measures Within Subjects ANOVA to examine changes in average urge ratings with-in the three baseline and two differential reinforcement conditions across time (ten consecutive 1-min intervals), we found no significant differences. Fig. 1 depicts data in 1 min sampling intervals; however the following analyses were conducted collapsed 10 min sampling intervals. There were no significant differences in average urge ratings (10 min sampling intervals) across the three baseline conditions: baseline 1 ($M = 3.95$, $SD = 1.42$), baseline 2 ($M = 4.60$, $SD = 2.03$), baseline 3 ($M = 4.41$, $SD = 1.94$), $F(2, 22) = 1.62$, *ns* (see Fig. 1). There were also no significant differences in average urge ratings (10 min sampling intervals) across the two differential reinforcement conditions: DRO1 0–10 min ($M = 3.74$, $SD = 2.26$), DRO1 11–20 min ($M = 3.80$, $SD = 2.13$), DRO1 21–30 min ($M = 3.83$,

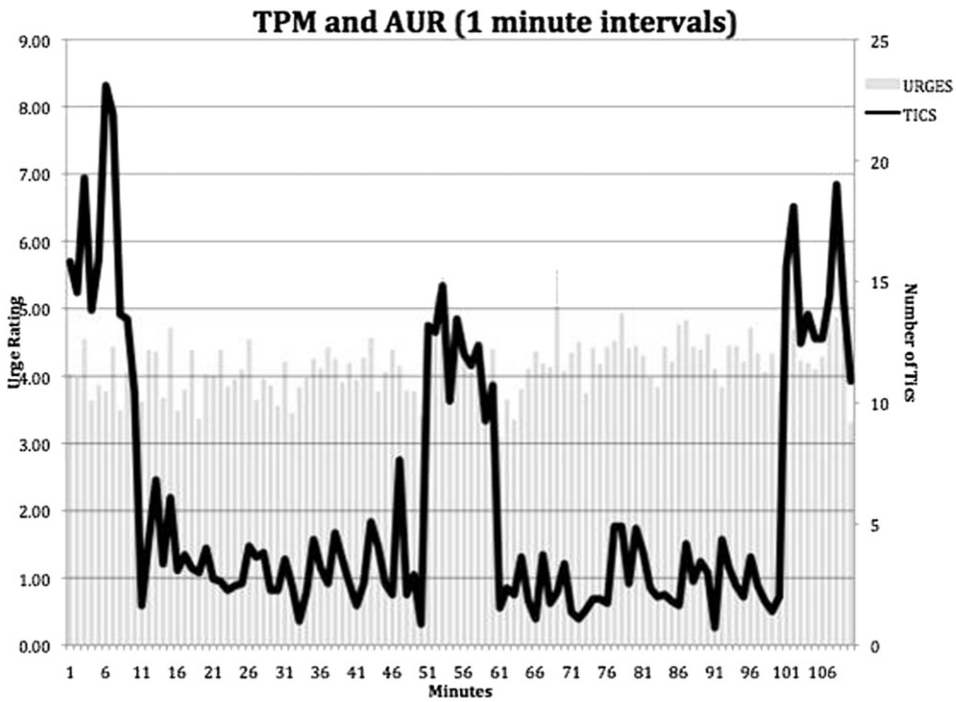

Fig. 1. Average urge ratings and number of tics completed per minute throughout all conditions (BL–DRO–BL–DRO–BL). Baseline (BL) condition: Minutes 1–10, 51–60, 101–110; DRO (tic freely) condition: Minutes 11–50, 61–100.

SD = 2.11), DRO1 31–40 min (*M* = 3.70, *SD* = 2.40) and DRO2 0–10 min (*M* = 3.69, *SD* = 2.34), DRO2 11–20 min (*M* = 4.02, *SD* = 2.50), DRO2 21–30 min (*M* = 4.01, *SD* = 2.43), DRO2 31–40 min (*M* = 3.86, *SD* = 2.41), $F(1,11) = .41$, *ns*. There was not a significant difference in average urge ratings when contrasting the aggregate baseline (*M* = 4.42, *SD* = 1.48) and differential reinforcement (*M* = 3.83, *SD* = 2.23) conditions, $F(1, 11) = .63$, *ns* (see Fig. 2).

Discussion

The comprehensive behavioral intervention for tics (CBIT) represents a safe, effective, non-pharmacological treatment for chronic tic disorders; however, it remains underutilized as a treatment option. Contributing factors include the perceived negative consequences of tic suppression and the lack of means through which tic suppression results in symptom improvement. The current study directly examined the ability of youth to suppress tics for prolonged periods, evaluated the perceived negative post-suppression consequences of tic suppression (i.e., a subsequent rebound in tic severity), and to explored the hypothesis that tics are, in part, maintained and exacerbated because tic completion results in temporary relief from unpleasant premonitory urges (i.e., negative reinforcement hypothesis). This study is also the first to directly examine if premonitory urge severity ratings significantly decrease during prolonged tic suppression (i.e., the urge habituation hypothesis) as an explanatory bridge for *how* behavioral treatments lead to symptom improvement.

In terms of age, gender ratio, tic severity and co-occurring psychiatric conditions, the current sample is comprised of youth who closely match participants in a prior non-pharmacological treatment studies which included tic suppression as a primary treatment component (Piacentini et al., 2010). Consistent with prior single-case studies (Himle & Woods, 2005; Woods & Himle, 2004), even without specific instructions regarding *how* to suppress tics, youth experience a significant, robust (72%), and stable reduction in tic frequency under extended periods of contingently reinforced tic suppression (i.e., 40 min). In contrast, during periods when tics are ignored, and in the absence of reinforcement for suppressing tics, tics were approximately 4.5 times more frequent. Additionally, as in Himle and Woods (2005), following periods of suppression, tic frequency simply returned to pre-suppression or lower levels. Taken together, these findings convincingly confirm that when environmental contingencies promote tic suppression, tic frequency decreases significantly, a decrease which can be maintained for prolonged periods of time (i.e., 40 min) even without specific instructions on how to suppress. These findings also run counter to the notion that suppressing one's tics will result in a subsequent explosion or rebound in tic frequency.

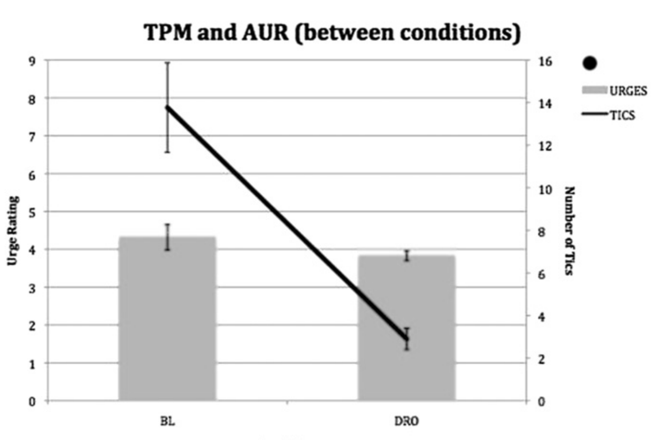

Fig. 2. Average urge ratings and number of tics completed collapsed between conditions. BL: Baseline (tic freely) condition; DRO: Differential reinforcement (tic suppression) condition. Error bars represent standard deviations.

In accordance with prior single-case studies (Himle et al., 2007), we hypothesized that urge ratings would be significantly lower during tic-freely conditions in contrast to initial tic suppression (i.e., negative reinforcement hypothesis). However, our aggregate data did not show the expected increase in self-reported premonitory urge ratings during initial tic suppression. The lack of a significant initial increase in premonitory urge ratings during suppression is consistent with results obtained in an exposure and response prevention for tics study (Verdellen et al., 2008) and would appear to dis-confirm the negative reinforcement hypothesis of tic maintenance. However, it is premature to entirely disregard the notion that a negative reinforcement cycle plays a role in the maintenance and/or exacerbation of tics. It may be the case that in youth with tics there is a pervasive belief that one must perform a tic to reduce an unpleasant premonitory urge in the same respect that a child with OCD may believe they must enact a compulsion or ritual to neutralize fear regarding a catastrophic event. It is generally agreed, even by patients with OCD (albeit the more insightful ones), that performing a compulsion does little to actually prevent catastrophes from occurring. Perhaps performing tics actually does little to alter urge intensity, but a strongly held 'belief' that performing tics decreases urges temporarily may be adequate to maintain and potentially exacerbate the behavior over time. At any rate, the current findings, taken together with Verdellen et al. (2008) are re-assuring in that they generally suggest that suppressing tics should not produce an initial, significant worsening of unpleasant premonitory urges.

We also hypothesized that self-reported premonitory urge ratings would significantly decrease during prolonged tic suppression, suggesting a habituation to the premonitory urge as an explanatory means by which behavioral treatments result in symptom reduction. However, our results significantly diverge from the urge habituation hypothesis and prior research in which tic suppression produced a linear reduction in verbal reports of premonitory urge intensity within and across 2-h treatment sessions (Verdellen et al., 2008). In the current study, urge intensity ratings remained relatively stable irrespective of study condition, suggesting that a habituation to the urge did not occur during prolonged tic suppression. It is entirely possible that urge ratings would have eventually lessened if tic suppression had been continued for longer periods of time (e.g., 2 h) or following additional reinforced tic suppression sessions. Nevertheless, the current study has some inherent methodological advantages over prior research which has suggested that habituation to urges occurs (Verdellen et al., 2008). First, in the current study, urge ratings were obtained more frequently (i.e., 10 s versus 15 min sampling intervals), which allows for more precise, real-time appraisals of changes in the intensity of premonitory urges. Additionally, because participants in current study were told that experimental conditions "did not represent a treatment", expectancies for improvement were less likely to influence verbal reports of discomfort (i.e., unpleasant premonitory urges) during experimental conditions. In as much, the current results suggest that tic suppression does not result in a change in premonitory urge ratings. Therefore, the habituation to the urge may not be the best explanation for *how* behavioral treatments result in symptom improvement, at least initially.

Again, while it may be that tic suppression eventually results in habituation to the premonitory urges, the current results suggest that premonitory urges may represent a more enduring, involuntary aspect of Chronic Tic Disorders. The premonitory urge has largely been neglected in the literature and is not currently central to a Chronic Tic Disorder diagnosis; however, Bohlhalter et al. (2006) using event-related functional magnetic imaging (fMRI), demonstrated that activation in paralimbic areas (i.e., anterior cingulate cortex [ACC], insular cortex, supplementary motor area [SMA]) and parietal operculum (PO) precede tics and may be associated with the vague, visceral 'need to move', which may constitute premonitory urges. It may be the case that premonitory urges, like error-related negativity (ERN) – presumably originating from the anterior cingulate cortex (ACC) – in pediatric OCD patients (Hajcak, Franklin, Foa, & Simons, 2008), do not change as a function of reduced symptoms. *Avoidance conditioning* and *extinction learning* of classical conditioning have been used to describe the development and maintenance of anxiety disorders as well as the means through which exposure-based cognitive behavioral therapy results in symptom improvement and have been supported by animal models. The current study suggests that initially reinforced tic suppression may simply create enhanced self-control and allow for inhibition of a behavioral response (i.e., tic) that has been 'conditioned' to occur in response to an unpleasant sensory experience (i.e., urge). Clearly, the possibility that classical "Pavlovian" conditioning principles are important to understanding the maintenance and exacerbation of tics and the ameliorative effects of tic suppression is controversial and requires investigation well beyond the scope of the current investigation.

This study was intentionally limited to a specific set of testable hypotheses with a specified subgroup of individuals. An attempt was made to determine the appropriate sample size and to control the effects of age, gender, ethnicity, medication, and comorbidity when appropriate; however, it was impossible to control all possible factors that may impact validity. As such, conclusions reflect an initial step in a line of research and may not be directly generalizable to all individuals diagnosed with a Chronic Tic Disorder. Additionally, the extent to which findings generalize to treatments including tic suppression or suppression of tics in other environments outside of clinic is unknown. While the current study demonstrated robust tic suppression without a post-suppression rebound in urges or tics, it is possible that rebound could occur following periods longer than 40 min. Another limitation involved the measurement of the premonitory urge. Premonitory urge assessment is difficult. While a substantial majority of individuals over ten years of age report premonitory urges (Leckman, Walker, & Cohen, 1993), direct physiological markers of the urge have not been reliably identified. Therefore, it was impossible to determine the objective accuracy of an urge rating; however, this is often the case with psychological constructs. As a result, researchers utilize self-report methodology to measure premonitory urges. The proposed project utilized the best available index of premonitory urges, which has been utilized successfully in research (Himle et al., 2007). However, it is possible that frequently obtaining premonitory urge ratings from participants may have increased the salience of urges and in turn influenced higher than anticipated urge ratings during baseline conditions.

In summary, the current study directly addresses concerns regarding the perceived negative consequences of tic suppression and to explore the negative reinforcement hypothesis of tic maintenance and exacerbation. This study is also represents the first direct examination of the urge habituation hypothesis as an explanatory bridge for *how* behavioral treatments lead to symptom improvement. Participants effectively suppressed tics for prolonged periods without a subsequent *rebound* in tic frequency. These findings address clinician, patient, and family fears regarding the perceived negative consequences of tic suppression treatments and highlight the safety of treatments involving tic suppression. When considered with findings from the multi-site, randomized controlled CBIT trial, the current findings suggest treatments that promote reinforced tic suppression should be vigorously promoted rather than avoided as treatment option. Perhaps most unanticipated, but intriguing findings were that urge intensity ratings remained unchanged across tic-freely and tic suppression conditions. These findings run counter to the negative reinforcement hypothesis of tic maintenance and the urge habituation hypothesis as an explanation for the ameliorative effects of non-pharmacological tic suppression treatments. The current findings instead suggest that premonitory urges, although not well-understood presently, may represent a more enduring physiological underpinning of Chronic Tic Disorders and may have etiological implications. Future studies are needed to examine the relationship between subjective urge ratings and neurophysiological activation in promising brain regions.

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