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An Examination of Electrodermal Activity During Tic Suppression in Adults

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An Examination of Electrodermal Activity During Tic Suppression in Adults

by

Bryan C. Brandt

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts
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Keywords: tics, tic suppression, electrodermal, galvanic skin response, Tourette Syndrome, adults, discrimination training

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ABSTRACT

Although tic disorders are diagnosed as neurological disorders, neurobehavioral models suggest that tics are controlled by premonitory urges that may be conditioned to become aversive through childhood, and that tics are exhibited to alleviate such phenomena. However, only indirect measures have been used to assess the presence of the premonitory urge. This study utilized self-report and GSR measurements to examine whether a punishing contingency conditioned stimuli to be aversive during conditions of tic suppression and whether punishing contingencies exacerbate aversive private phenomena in two adults. Results indicated that conditions of response cost (RC) and differential reinforcement (DRO) were effective at reducing the number of tics compared to baseline. Moreover, GSR was unrelated to urge and suppression conditions despite higher self-reported urge ratings in DRO and RC conditions. Implications of findings are discussed.
INTRODUCTION

Tic Disorders including, Tourette’s Syndrome (TS), and Chronic Motor Tic Disorder (CTD), and Chronic Vocal Tic Disorders (VTD), are neuropsychiatric disorders with a typical age of onset around 5 or 6 years old. TS, CTD, VTD are characterized by tics, which are sudden, rapid, recurrent movements or vocalizations that fluctuate in form, frequency, intensity and severity (APA, 2000). Tic Disorders occur in 0.04% to 3.8% of the population (APA, 2000; Comings, Himes, & Comings, 1990; Jinet al., 2005; Khalifa, & von Knorring, 2003; Kurlan et al., 2001) and are believed to be the result of a dysfunction of the thalamus, basal ganglia, and prefrontal cortex (Walkup, Mink, & Hollenback, 2006).

Tics can occur in two forms, motor or vocal, and can be of complex or simple type. Simple motor tics entail sudden, brief, meaningless motor movements such as eye blinking, eye movements, grimacing, mouth movements, head jerks, and shoulder shrugs. Complex motor tics are slower, longer, more purposeful movements, usually consisting of a series of simple tics occurring in an orchestrated pattern. Simple vocal tics are sudden meaningless sounds or noises, such as throat clearing, coughing, sniffing, or other sound thrusts. Complex vocal tics are sudden more meaningful utterances such as syllables, words, obscene aggressive words, or echolalia (APA, 2000). Authors also report physical sensations prior to the occurrence of tics (Turtle & Robertson, 2008).

Leckman, Walker, and Cohen (1993) examined phenomena identified as premonitory urges
These urges were self-reported as private somatosensory stimulation delineated as a rise in tension or anxiety that precede tic behavior, often localized to distinct topographies. Of 135 participants ages 8-71, 93% self-reported experiencing a PU, and 84% self-reported relief upon tic offset. Additionally, 93% self-reported tics as voluntary movements, contradicting theories attributing tics as involuntary motor/vocal behaviors.

Following the Leckman et al. (1993) study, contemporary behavioral models posited an increase in intensity of the PU prior to tic expressions, subsequently resulting in alleviation of aversive stimulation post tic expression. Preliminary evidence was provided by Himle, Woods, Conelea, Bauer, and Rice (2007). During conditions of tic-suppression, three out of five participants self-reported an increase in PU, suggesting a negative reinforcement function when reduction of the urge was prevented during suppression.

To examine the aversive qualities of the PU, Woods, Piacentinie, Himle and Chang (2005) investigated the PU in children, aged 8-16 years old diagnosed with TS. For children greater or equal to the age of 11, there were significant positive correlations between tic severity and self-report measures of negative affect, somatic complaint, and social withdrawal; suggesting the higher frequency of tics, the greater magnitude of internal and external negative consequences the individual contacts. These results are consistent with research on the quality of life in children diagnosed with TS. Children with TS experience a lower quality of life and a higher sense of peer victimization as a result of their tics. Furthermore, they are significantly more represented in special education settings as a result of their tics (Bawden, Stokes, Camfield, Camfield, & Salisbury, 1998; Culter, Murphy, Gilmour, & Heyman, 2009; Olweus, 1993; Packer, 2005; Storch et al., 2007; Zinner, Conelea, Glew, & Budman, 2011). Conversely, significant correlations did not manifest in children below the age of 10, suggesting the PU may
begin as a neutral stimulus and become conditioned to develop aversive qualities (Woods, 2005). Contrary to the findings of Woods et al. (2005), Steinberg et al. (2010) revealed insignificant correlations between the younger and older age groups in a replication study using an Israeli population. However, differentiated populations may account for these discrepancies. Woods utilized individuals who did not receive prior behavioral treatment for their tics, while Steinberg did not utilize treatment as a criterion for exclusion.

Neurobehavioral theories regarding the epidemiology of TS regard tics as operant behavior. An individual engages in tics because they alleviate the PU. Urges may begin as neutral sensations, but undergo aversive conditioning through childhood (Woods, 2005). Similar phenomena have been evidenced experimentally in rats, when neutral stimuli are paired with unconditioned stimuli that elicit unconditioned fear responses, leading to conditioned stimuli eliciting conditioned fear responses – that is, the neutral stimulus acquires aversive properties. (Kamin, Brimer, & Black 1963; Rescorla & Solomon, 1967). Still, little is known about the development of the PU beyond what some authors theorize (Woods, 2005).

The PU is covert, therefore, direct measurement to validate its occurrence is not possible (Himle et al., 2007; Leckman et al., 1993; Turtle & Robertson, 2008). However, developments in neurological research propose a link between Tic Disorders and somatosensory and sympathetic systems, specifically those found in sensory-motor cortex (Thomalla et al., 2009). One such study examined the impact of a biofeedback system utilizing galvanic skin response to reduce tic frequencies. Nagai, Cavanna, and Critchley (2009) demonstrated that sympathetic nervous system arousal was positively correlated with the rate of tic behavior, suggesting that sympathetic nervous system arousal may be part of the biological processes underlying the PU. However, even though evidence suggests that tics occur post PU, tics can come under the control
of other antecedents.

Woods, Walther, Bauer, Kemp and Conelea (2009) demonstrated that tics could be put under stimulus control through conditions of 10-s differential reinforcement of other behavior (DRO-10), verbal instruction (VI), and baseline (BL). During VI conditions, an orange light on a token dispenser was illuminated while the participant was instructed to suppress his or her tics. Through DRO-10 conditions a blue light was illuminated and reinforcement was delivered for every 10-s tic-free interval. Within baseline conditions, lights were not illuminated and participants were asked to tic as freely as they wanted to. Participants were exposed to these conditions randomly three times. Following the experimental conditions, a test for stimulus control demonstrated a reduction in the rate of tics through DRO-10 conditions greater than VI and BL conditions even when the contingency was not in place. This finding suggests that specific stimuli can be conditioned to control tic behavior by the consequences of tic behavior that occur in their presence.

The purpose of this study is to (a) replicate earlier research in the development of stimulus control over tics (Woods et al., 2009) utilizing response cost and DRO contingencies. It is predicted that response cost will result in tic suppression similar to research by Capriotti, Brandt, Ricketts, Epsil, and Woods (2012), however urge ratings will be greater in response cost conditions, both in self-report, and measured by GSR. A second purpose is to test the feasibility of a GSR system for measuring the premonitory urge.
METHOD

Participants

Two participants were recruited from the Tourette’s Syndrome Association website. Jack was a 48-year-old caucasian male diagnosed with TS. Jane was an 18-year-old caucasian female diagnosed with TS. Both were included in the study because they (a) had received a diagnosis of TS from a neurologist or medical doctor evidenced by a signed diagnosis form, (b) had a Yale Global Tic Severity Scale (YGTSS; Leckman, Riddle, Hardin, & Ort, 1989) severity score of greater than or equal to 14 for a TS diagnosis, (c) had to tic at a rate of at least once per min during a 5-min preliminary observation period, and (d) had not received behavioral treatment for tics. Table 1 illustrates additional demographic information.

Table 1. Demographic information of participants. YGTSS stands for Yale Global Tic Severity Scale, and PUTS stands for Premonitory Urge for Tics Scale.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age</th>
<th>Diagnosis</th>
<th>YGTSS Motor</th>
<th>YGTSS Vocal</th>
<th>YGTSS Total</th>
<th>PUTS Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jack</td>
<td>Male</td>
<td>48</td>
<td>TS</td>
<td>16</td>
<td>16</td>
<td>32</td>
<td>26</td>
</tr>
<tr>
<td>Jane</td>
<td>Female</td>
<td>18</td>
<td>TS</td>
<td>15</td>
<td>9</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

Setting

Experimental conditions were conducted at the University of South Florida’s Interdisciplinary Center for Evaluation and Intervention (ICEI) clinic. The ICEI clinic contains
two rooms (each 20 m by 20 m) equipped with one-way mirrors, ceiling mounted cameras, hard
disk video recording, and an evaluation and interview room that retains anonymity for visitors.

Materials

Demographic form. Demographic information was collected on the participant’s age,
diagnosis, and gender (see Appendix A).

Premonitory urge for tics scale. The PUTS is a 9-item self-report measure that
evaluates premonitory urges on a 0-4 point ordinal scale with anchor points corresponding to the
following: 1 = “not at all true,” 2 = “a little true,” 3 = “pretty much true,” 4 = “very much true.”
Summing the scores produces a rating of the frequency and presence of pre-tic somatosensory
phenomena. The PUTS has good internal consistency (α=.81) and good temporal stability: week
1 (r=.79), and week 2 (r=.86) (Woods et al., 2005; see Appendix B).

Yale global tic severity scale. The YGTSS is a parent and child interview that produces
severity ratings utilizing a 0 to 5 point Likert scale for the number, frequency, intensity, and
complexity of motor and vocal tics in addition to an overall impairment rating. The YGTSS has
good internal consistency, and inter-rater reliability (Leckman et al., 1989; see Appendix C).

Manipulation check form. Following each condition and at the beginning of the first condition,
a manipulation check was administered to assess compliance with and comprehension of
instructions. Questions asked: “What were you supposed to do in the prior condition?” “Were
you supposed to be trying to stop your tics?” and “How did you loose tokens during the prior
condition?” (see Appendix D).

Premonitory urge thermometer. The urge thermometer was adopted from the 9-point
“feelings thermometer” rating scale used in the Anxiety Disorders Interview Schedule for DSM-
IV ADIS-IV (Silverman & Albano, 1996). The urge thermometer utilized an ordinal scale with
anchor points signifying from left to right: “not at all,” “a little bit,” “some,” “a lot,” and “very, very much.” The urge thermometer has been utilized in research to self-report urge phenomena (Conelea, Woods, & Brandt, 2011; Himle et al., 2007, Capriotti et al., 2012; see Appendix E).

**Apparatus**

**Physiological measurement device.** Galvanic skin response was recorded utilizing Mindfield’s eSense skin response biofeedback system. Two electrodes were attached to John and Jane’s left index and middle finger using Velcro straps, and connected to the headphone jack of an Apple Ipad. Mindfield’s proprietary software was utilized to record GSR level.

**Video recording equipment.** Two ceiling mounted cameras positioned in opposing corners of the room recorded closed circuit video of participants, while a hidden microphone recorded audio. Video and audio was monitored in the observation room during conditions and recorded onto hard drives accessible only to personnel of the ICEI clinic.

**Computer systems and software.** One laptop computer in the observation room running programmed software recorded and controlled visual feedback of a computer monitor in the experimental room. Upon initialization the software prompted the observer to enter the participant name, and then randomized and counterbalanced the condition order and count. During conditions, corresponding tokens were displayed on the connected monitor in the experimental room. When a tic occurred, the observer depressed the ‘m’ key on the keyboard to record a motor tic, and the ‘v’ key on the keyboard to record a vocal tic. The software would remove a token, add a token after a specified temporal duration, or do nothing depending on the type of condition. All actions were recorded to ms accuracy and stored into a database on the computer.

**Light device.** To replicate the environmental conditions in the Woods et al. (2009) study,
a light device consisting of a plastic electrical control box with an orange and blue light was created. A remote control box, outfitted with two toggle switches provided power to the light box through an extension cord that ran from the observation room to the experimental room. The light device was placed upon a desk in front of the participant, adjacent to the computer monitor.

**Target Behaviors and Data Collection**

Tics and GSR level were recorded using a continuous recording method. Tics were recorded by an observer watching recorded conditions edited to their corresponding lengths utilizing custom software which recorded tics at ms value. These values were converted to tenths of a s and mapped onto GSR data using Microsoft Excel.

**Operational definitions of tics.** Operational definitions for each participant’s tics were obtained from the YGTSS and pre-experiment observational period. The investigator reviewed pre-experiment observation video recording, and outlined each tic movement descriptively. See Table 2 for a list of operation definitions.

**Inter-observer agreement.** Inter-observer agreement was calculated across 25% of all conditions utilizing a frequency within interval recording method. An independent coder watched video recordings of randomized conditions and scored for tics utilizing custom software and operational definitions. Each 5-min condition was divided into 10-s intervals. Agreement
Table 2.

*Operational definitions for John and Jane’s tics.*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Type of Tic</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>Simple vocal grunt</td>
<td>Sudden forced air resulting in a quick grunting sound. Varies in intensity from a soft grunt to a loud grunt. Each instance counts as 1 tic. Clearing the throat does not count.</td>
</tr>
<tr>
<td></td>
<td>Simple motor mouth</td>
<td>Any movement of the bottom left lip or bottom right lip, or any extension of the lips up or down that cause pursing of the lips and is accompanied by a corresponding lower jaw movement. Tic is counted from onset of movement to specified direction and return to resting position.</td>
</tr>
<tr>
<td></td>
<td>Simple motor shrug</td>
<td>A 2-3 second lifting from the shoulder from a resting position upwards and return to resting position. Each instance is counted as one.</td>
</tr>
<tr>
<td>Jane</td>
<td>Simple motor head jerk</td>
<td>Any sudden movement of the chin and head upward, downward, left, right or any combination of the above in a snapping motion. Each instance is counted as one.</td>
</tr>
<tr>
<td></td>
<td>Simple motor mouth</td>
<td>Any movement of the left and/or right corner of the upper lip upwards. Each instance is counted as one.</td>
</tr>
<tr>
<td></td>
<td>Simple motor eye blink</td>
<td>A deliberate and forceful closing of the eyes and lower of the eyebrow for longer than half of a second. Each instance is counted as one.</td>
</tr>
</tbody>
</table>

was calculated by dividing the smaller of the interval scores between the primary investigator and the independent coder by the larger number of scores in each 10-s interval to produce a percentage of agreement at each interval. These percentages were summed and divided by the
number of intervals for an overall agreement per condition. Mean agreement score was 89% for all conditions (range, 83% to 87%).

**GSR measurement.** Participants’ electrodermal activity was recorded at 10 hertz with 18-bit resolution using Mindfield’s eSense skin response biofeedback system. Information on time in tenths of s and level of electrodermal response in microsiemens was stored, sent electronically, and imported into a Microsoft Excel spreadsheet for analysis.

**Procedures**

**Assessment, qualifying data measurement.** Upon arrival, participants underwent an assessment to determine eligibility criteria that was conducted in a private room within the ICEI clinic. Participants were informed of the purpose and conditions of the study to the extent allowed to preserve deception and consent was obtained prior to any data collection. Assent was attained from the participant following experimental conditions, during the debriefing stage. Following consent, data on demographic information, tic symptom and severity utilizing the YGTSS, and presence of the premonitory urge utilizing the PUTS were collected. When participants met YGTSS and PUTS qualifying criteria, a 5-min observation period in the experimental room was conducted to ensure tic per min qualifying criterion was met.

**Experimental conditions.** Participants were covertly videotaped during experimental conditions utilizing the video recording system. Video recording of tics was conducted in accordance with previous research (Chappell, McSwiggan-Hardin, Scahill, & Rubenstein, 1994; Piacentini et al., 2006), and deception was utilized to control for reactivity (Himle et al., 2006; Piacentinie et al., 2006).

Before participants began experimental conditions, they were seated in the experimental room and told that it was an advanced “tic detector” that would count their tics, and that during some
conditions an orange or a blue light may illuminate. Participants were further instructed that the goal of the experiment was to earn tokens that would later be traded in for money. Depending on the condition, participants were instructed that they could earn or lose tokens by ticcing. The use of the premonitory urge thermometer was taught to the participant, ensuring normative responses corresponded to rankings on the thermometer through novel examples demonstrating high/low elicitation of urges. Participants were instructed that these urge ratings would be taken before and after every condition.

While the GSR sensor was attached to the participant, the investigator explained that the device would be accumulating physiological data on them throughout all conditions, and that they should restrict movement of their left hand for accurate collection.

At the start of each condition, instructions were given explaining the condition (see Appendix F), and participants were asked to repeat the instructions to ensure understanding. Before the first condition, and after each condition, participants were asked to rate their premonitory urge using the urge-scale thermometer. Manipulation checks were conducted after each condition, to ensure that the participant understood the task (see Appendix D).

**Stimulus discrimination training.** During stimulus discrimination training, participants were randomly exposed to 5 min counterbalanced conditions of baseline (BL), response cost (RC), and differential reinforcement (DRO) twice. During all suppression conditions (RC and DRO) the investigator and the research assistant observed the participant through a one-way mirror. The investigator called out “motor” or “vocal” when the corresponding tic had been observed. The research assistant, if he or she hadn’t already, depressed the corresponding key to annotate that a tic had occurred.

**Baseline (BL).** During baseline conditions, participants were seated in the experimental room in
front of the computer monitor and light machine. They were asked to tic as much or as little as needed, and that they were not going to earn or lose tokens contingent on tics, however, the tic detecting room would detect their tics. No lights were illuminated on the light device, and no tokens appeared or disappeared on the computer monitor.

**Response cost (RC).** In response cost conditions, the computer displayed 60 tokens at the beginning of the condition, and the blue light was illuminated throughout the entire condition. Participants were asked to suppress their tics, and that each occurrence of an unsuppressed tic resulted in a loss of a token displayed on the computer screen. They were instructed that the room would detect their tics and control the token loss, however, token loss was controlled by the research assistant depressing of the ‘m’ or ‘v’ key in the observation room.

**Differential reinforcement (DRO).** During differential reinforcement, the participants were instructed to suppress their tics and for every 10-s tic-free interval, the tic detecting room would reward them with a token appearing on the screen. Through this condition, the orange light on the light machine was illuminated, and the research assistant in the observation room controlled token reward.

**Test of stimulus control.** After stimulus discrimination training, the participant was re-exposed to the light stimulus associated with BL, DRO, and RC conditions, however no instructions were provided during this phase. Participants did not earn or lose tokens, however the blue light was illuminated during the response cost condition, the orange light was illuminated during the DRO condition, and no light was illuminated during the Bl condition.

**Accuracy of token removal, award.** Accuracy of token removal was calculated utilizing a frequency within interval method for response cost conditions and total count for DRO conditions. Token removal was considered accurate if it occurred within a plus or minus 3 s
differential around a tic during RC conditions. Each 5-min condition was divided into 10-s intervals, and the total correct for each interval was divided by the total possible in each interval multiplied by 100. These scores were averaged across all intervals to provide an overall rating of token removal. A token was considered accurately awarded during DRO conditions if it occurred after a 10 s tic free interval with a plus or minus discrepancy of 3 s. Total accurately awarded was divided by total awarded and multiplied by 100 to calculate a percentage.

**Instruction integrity.** To ensure that the experimenter instructed each condition properly, an independent coder collected data on the percentage of accurate instructions that were delivered during each condition, utilizing a task analysis form (See Appendix G).

**Post experiment debriefing.** After the experiment the participant was debriefed to the nature of the study and the use of deception, and was offered a tour of the experimental room. During this time assent was obtained from both participants for the use of video recordings and data.
RESULTS

Figure 1 illustrates tics per min during stimulus discrimination training and test for stimulus control conditions for John and Jane. During stimulus discrimination training, John’s mean BL tic rate was 57 tics per min, which decreased to a mean rate of 1.6 during DRO conditions and 3.4 through RC conditions. Jane exhibited a mean tic rate of 11 tics per min during baseline conditions that decreased to a mean of 4.8 during DRO conditions and 3.4 for RC conditions. The higher rates of tics during BL conditions than during DRO and RC conditions suggest the participants effectively suppressed their tics when contingencies were in place to do so. Additionally, tic rates were similar between DRO and RC conditions during stimulus discrimination training, showing both conditions were equally effective at reducing tic rates.

Stimulus control was not established during test for stimulus control conditions as rates increased to baseline levels for both participants. John’s RC and DRO tic rates increased to 56.8 tics per min while Jane’s RC and DRO tic rates increased to 8.8 and 10 tics per min, respectively.

Differential patterns of mean GSR were not observed among conditions (see Figure 2). Although tic rates were much lower in the DRO and RC conditions than in baseline, there were no corresponding differences in mean GSR levels. In BL1, John’s mean GSR level was at 1.39 µS and his rate of tics was 52.6 per min. Mean GSR decreased to 1.22 µS throughout RC1, DRO1, RC2, and BL2 and tics decreased to a mean of 2.87 per min during RC1. However, this
Figure 1. Tics per minute across baseline (BL), differential reinforcement (DRO) and response cost (RC) conditions for John and Jane.
Figure 2. Average galvanic skin response measured in microsiemens with min and max values and tics per minute data during each condition for John and Jane. Note that the average GSR scale is different for each participant, and a * indicates a condition in which the stimulus was presented but no contingency was enforced.
pattern of higher GSR during baseline conditions with higher tic levels and lower GSR levels with lower tic levels in RC and DRO phases was not replicated in the remainder of John’s data and was never shown in Jane’s data. Thus, GSR and tic data suggest no relationships between type of condition, rate of tics, and mean GSR level.

Self-reported urge ratings and tics per min for John and Jane are illustrated in Figure 3. John self-reported higher urge ratings in RC1, RC2, DRO1, and DRO2 ($M = 7.5$) than in BL1 and BL2 ($M = 6$) with coinciding tic rates high in BL1 and BL2 ($M = 48.3$) and low in RC1, RC2, DRO1, and DRO2 ($M = 2.55$). Self-reported urge rating for RC3 returned to baseline levels while rate of tics remained low at 1.6 per min. Self-report urge decreased in BL3, DRO3, and RC4 ($M = 5.3$) as tic rates increased ($M = 62.6$). Jane self-reported higher urge ratings through DRO1, DRO2, RC1, and RC2 ($M = 6$) than in BL1, BL2, and BL3 ($M = 4.3$). Jane’s rates of tics were higher in BL1, BL2, and BL3 ($M = 11$) than DRO1, DRO2, RC1, and RC2 ($M = 4.1$). In RC3 and DRO3 self-reported urge ratings remained at baseline levels ($M = 4.5$) and mean rate of tics increased to 9.4. These results show that both participants self-reported higher urge ratings during suppression conditions than in BL conditions, suggesting the urge to tic was greater when in conditions of contingency backed suppression than conditions of test for stimulus control or free to tic baseline.

Figure 4 illustrates an example of continuous data on tic occurrence and GSR level for John. No temporal relation was observed between the occurrence of a tic and the subsequent fluctuation and level of GSR for John or Jane. There was no evidence of increased GSR level immediately prior to a tic occurrence suggesting that GSR was not a sensitive measure of the premonitory urge for these participants.
Figure 3. Self-reported urge ratings during conditions and average tics per minute throughout all conditions for John and Jane. A * indicates a condition in which the stimulus was presented but no contingency was in place.
Figure 4. An example of continuous data measurement from John’s BL1, RC1, and DRO1 conditions. The x-axis represents time, and the y-axis represent GSR level in microsiemens. GSR readout is outlined in blue, while grey lines indicate occurrences of motor and/or vocal tics.

Token delivery and removal accuracy for John and Jane was 88% (range, 82% to 96%), and 88% (range, 82% to 92%) respectively. Pre and post condition manipulation checks for instructional compliance by the participant indicated 100% adherence, with no participant requiring additional or corrective instructions for any condition. Independent evaluator scoring on instructional integrity during conditions was 100%.
DISCUSSION

The results of this study are consistent with previous research showing the suppressive effects of DRO and RC with tics. However, the results indicate a lack of support for the development of stimulus control over tics utilizing a response cost contingency among adults diagnosed with TS. Tic suppression was established as evidenced by the differential tic rate between baseline and contingency conditions, however, this effect did not maintain when the $S^D$ was present in the absence of the contingency, as evidenced by the return to BL levels of tics in the test for stimulus control conditions. This could be due to the participants discriminating the absence of the contingency in the test for stimulus control conditions. In addition, it could be due, in part, to the small number of conditions that occurred in stimulus discrimination training.

In the Woods et al. (2009) study, each participant was exposed to stimulus discrimination training conditions three times as opposed to the current study which only exposed participants twice to each condition. Additionally, the apparatus utilized in the Woods et al. (2009) study was different. Lights appeared on a token dispenser that dispensed physical tokens while during this study a light device sat upon the table separate from a computer monitor that displayed tokens. Moreover, the Woods et al. (2009) study utilized ten children aged 9-15 while the current study employed two adults aged 18 and 43.

Self-reported urge ratings during conditions featuring contingency shaped suppression (RC and DRO) during stimulus discrimination training were similar, suggesting no differences between the effects of a punishing contingency and a reinforcing contingency on the urge.
Higher urge ratings in DRO conditions compared to BL conditions have been reported in similar tic suppression research (Capriotti et al., 2012; Conelea et al., 2011; Himle et al., 2007) and similar urge ratings of DRO and RC have been reported as well (Capriotti et al., 2012). However, self-reported urge ratings from the current study are more pronounced in separation from baseline levels during discrimination training in suppression conditions. This could be due, in part, to the younger population utilized in previous research. It is hypothesized that the urge does not become salient until the age of 11 (Leckman et al., 1993; Woods et al., 2005), therefore older populations may be more accurate than younger populations in their reporting of the level of urge they experience. These effects are not explained by greater participant tic and urge severity, as the current participants did not differ in tic severity measured by YGTSS score and urge severity measured by PUTS score compared to adult participants in psychometric testing of the PUTS (Crossley, Seri, Stern, Robertson, & Cavanna, 2014; Reese et al., 2014) and youth in suppression studies (Capriotti et al., 2012; Conelea et al., 2011; Woods et al., 2005).

Rate of tics did not differ between DRO and RC, however DRO and RC rates were much lower than BL. The similar results for RC and DRO imply that punitive contingencies are as effective at suppressing tics as reinforcing contingencies. These findings have been similarly reported (Capriotti et al., 2012), however they contrast with research in which punishment contingencies demonstrated greater effectiveness at suppressing behavior than reinforcement contingencies (Costantini & Hoving, 1973; Penney & Lupton, 1961). Capriotti et al. (2012) suggest a lack of difference between RC and DRO suppression conditions could be explained by a lack of magnitude of the punisher, however, it could also be attributed to the response cost paradigm in general. Indeed prior research has provided similar results in the reduction of behavior when reward and punishment contingencies provided undifferentiated results (Hundert,
1976; Iwata & Bailey, 1974). It has also demonstrated that suppressing responding depends on schedule of punishment (Bradshaw & Szabadi, 1978), duration of the contingency (Conyers et al., 2004) and magnitude related to punishment schedule (Pietras, Brandt, & Searcy, 2010). The authors suggest the lack of differences in DRO and RC can be attributed to the small magnitude punisher, schedule, and duration of response cost contingency.

Galvanic skin response did not predict or measure the premonitory urge, evidenced by a lack of temporal relation between the onset of a tic and subsequent GSR levels and small, inconsistent differences in GSR levels between conditions.

The results of this study suggest tic suppression does not lead to heightened states of autonomic arousal. Previous research has indicated that heightened states of arousal are associated with greater differences in tic frequencies between conditions of arousal and relaxation (Nagai et al., 2009). In this study GSR levels did not fluctuate between conditions noticeably. Contrary to findings on skin conductance in which punishment showed a higher level of skin conductance (Gomez & McLaren, 1997), a mild punishing contingency did not arouse the individual any more than reinforcement or baseline conditions.

Heightened galvanic skin responses have been associated with stress responses (Kimmel & Hill, 1961; Reinhardt, Schmahi, Wüst, & Bohus, 2012) and stressful activities have been shown to interfere with tic suppression (Conelea et al., 2011). However, no differences in GSR between baseline and suppression conditions, in spite of great differences in tic rate, suggests suppression is not stressful for the individuals even if they are more responsive to stress (Chappell et al., 1994).

A limitation to this study was the method of GSR collection. Data were collected on an Ipad, which was placed behind the computer monitor in front of the participant. At times during
conditions it appeared that participants were watching GSR levels fluctuate for short intervals of time. Although complete understanding of GSR levels was improbable because numbers and levels were not visible from a distance, some form of biofeedback could have occurred. When asked whether or not the participants were watching, Jack responded that he was at times, but the data “didn’t mean anything to him” and Jane denied observing GSR levels despite the investigator noticing her occasionally look at the Ipad screen.

Another limitation of this study was the small number of participants. The participants demonstrated different levels and patterns of responding with GSR during the various conditions, suggesting generalizability of these findings might be weak without additional data. It is unclear whether the participants were diagnosed with any comorbid disorders (e.g., anxiety disorder), which if present, may have accounted for the contrasting results in GSR levels.

The use of adults may have compromised the role of deception. Past research on tic suppression utilizing deception on youth has instructed the participants that the more tokens that are earned the greater the toy prize will be at the completion of the study. Similarly, adults during this study were instructed that the more tokens they earned the greater the percentage of the compensation they would receive. However recruitment material stated that participation would be compensated in full, and this was reiterated during the consent process. Future research should focus on an examination of magnitude of response cost, schedule of response cost, and length of the punishing condition. The current study and previous research (Capriotti et al., 2012) demonstrated equivalent results in punishment and reinforcement contingencies, therefore further exploration is needed to understand the role of negative contingencies on the development of the premonitory urge.

Additional research is required on tic suppression in adults. Little to no research is available on
tic suppression with adult populations. It is assumed that the functions of tics are similar to those found within youth, however no peer-reviewed studies on tic suppression utilizing single subject design are known.

The study was the first to examine the effects of tic suppression with adults in a single subject design. Additionally, this study was the first to examine the relationship between GSR and tics to identify whether physiological measures can identify premonitory urges and whether these vary by condition. This study added to the literature by demonstrating the suppressive effects of DRO and RC with adults and demonstrating that tic suppression does not cause physiological arousal.
REFERENCES


APPENDICES

Appendix A: Background information sheet

Participant ID #: _____________________________ Today’s Date: _____________________________

Participant Name: ____________________________________________________________

Age: ___ ___ (yrs) ___ ___ (mos)

Gender: Male Female
Appendix B: Premonitory urge scale

Subject’s Number__________________ Date____________________
Informant________________________

Please answer the following questions. Try to be very honest when you answer them. Circle the number that best describes how you feel.

Not at all true  A little true  Pretty much true  Very much true

1. Right before I do a tic, I feel like my insides are itchy. 1234
2. Right before I do a tic, I feel pressure inside my brain or body. 1234
3. Right before I do a tic, I feel “wound up” or tense inside. 1234
4. Right before I do a tic, I feel like something is not “just right.” 1234
5. Right before I do a tic, I feel like something isn’t complete. 1234
6. Right before I do a tic, I feel like there is energy in my body that needs to get out. 1234
7. I have these feelings almost all the time before I do a tic. 1234
8. These feelings happen for every tic I have. 1234
9. After I do the tic, the itchiness, energy, pressure, tense feelings, or feelings that something isn’t “just right” or complete go away, at least for a little while. 1234
Appendix C: Yale global tic severity scale
MOTOR TIC SYMPTOM CHECKLIST (Check motor tics present during past week.)

- Simple Motor Tics (Rapid, Darting, "Meaningless"):
  - Eye blinking
  - Eye movements
  - Nose movements
  - Mouth movements
  - Facial grimace
  - Head jerks/movements
  - Shoulder shrugs
  - Arm movements
  - Hand movements
  - Abdominal tensing
  - Leg, foot, or toe movements
  - Other (describe):
    - Other (describe):

- Complex Motor Tics (Slower, "Purposeful"):
  - Eye movements
  - Mouth movements
  - Facial movements or expressions
  - Head gestures or movements
  - Shoulder movements
  - Arm movements
  - Hand movements
  - Writing tics
  - Dystonic postures
  - Bending or gyrating
  - Rotating
  - Leg or foot or toe movements
  - Blocking
  - Tic related compulsive behaviors (touching, tapping, grooming, evening-up)
  - Copropraxia
  - Self-abusive behavior
  - Paroxysms of tics (displays), duration ___ seconds
  - Disinhibited behavior (describe)*
    - Other (describe):
      - Other (describe):


### PHONIC TIC SYMPTOM CHECKLIST

(Chk phonic tics present over the past week.)

- **Simple Phonic Symptoms** (Fast, "Meaningless" Sounds):
  - Sounds, noises (circled: coughing, throat clearing, sniffing, or animal or bird noises)
  - Other (list):

- **Complex Phonic Symptoms** (Language: Words, Phrases, Statements):
  - Syllables (list)
  - Words (list)
  - Coprolalia (list)
  - Echolalia
  - Palalalia
  - Blocking
  - Speech atypicalities (describe)
  - Disinhibited speech (describe)*

* Do not include disinhibitions in ratings of tic behaviors

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(No specific tic behaviors)

(Chk phonic tics present over the past week.)

- **Simple Phonic Symptoms** (Fast, "Meaningless" Sounds):
  - Sounds, noises (circled: coughing, throat clearing, sniffing, or animal or bird noises)
  - Other (list):

- **Complex Phonic Symptoms** (Language: Words, Phrases, Statements):
  - Syllables (list)
  - Words (list)
  - Coprolalia (list)
  - Echolalia
  - Palalalia
  - Blocking
  - Speech atypicalities (describe)
  - Disinhibited speech (describe)*

* Do not include disinhibitions in ratings of tic behaviors

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(No specific tic behaviors)
### INTENSITY

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<tr>
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<tr>
<td><strong>SEVERE INTENSITY</strong></td>
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</table>

**Definition:**
- **Absent:** Tics not visible or audible (based solely on patient's private experience) or tics are less forceful than comparable voluntary actions and are typically not noticed because of their intensity.
- **Minimal:** Tics are not more forceful than comparable voluntary actions or utterances and are typically not noticed because of their intensity.
- **Mild:** Tics are more forceful than comparable voluntary actions but are not outside the range of normal expression for comparable voluntary actions or utterances. They may call attention to the individual because of their forceful character.
- **Moderate:** Tics are more forceful than comparable voluntary actions or utterances and typically have an "exaggerated" character. Such tics frequently call attention to the individual because of their forceful and exaggerated character.
- **Marked:** Tics are extremely forceful and exaggerated in expression. These tics call attention to the individual and may result in risk of physical injury (accidental, provoked, or self-inflicted) because of their forceful expression.

### COMPLEXITY

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<tr>
<td><strong>SEVERE</strong></td>
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</table>

**Definition:**
- **None:** If present, all tics are clearly "simple" (sudden, brief, purposeless) in character.
- **Borderline:** Some tics are not clearly "simple" in character.
- **Mild:** Some tics are clearly "complex" (purposive in appearance) and mimic brief "automatic" behaviors, such as grooming, syllables, or brief meaningful utterances such as "ah, huh," "hi" that could be readily camouflaged.
- **Moderate:** Some tics are more "complex" (more purposive and sustained in appearance) and may occur in orchestrated bouts that would be difficult to camouflage but could be rationalized or "explained" as normal behavior or speech (picking, tapping, saying "you bet" or "honey", brief echolalia).
- **Marked:** Some tics are very "complex" in character and tend to occur in sustained orchestrated bouts that would be difficult to camouflage and could not be easily rationalized as normal behavior or speech because of their duration and/or their unusual, inappropriate, bizarre or obscene character (a lengthy facial contortion, touching genitals, echolalia, speech atypicalities, longer bouts of saying "what do you mean" repeatedly, or saying "fu" or "sh").
- **Severe:** Some tics involve lengthy bouts of orchestrated behavior or speech that would be impossible to camouflage or successfully rationalize as normal because of their duration and/or extremely unusual, inappropriate, bizarre or obscene character (lengthy displays or utterances often involving copropraxia, self-abusive behavior, or coprolalia).

### INTERFERENCE

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<tr>
<td><strong>SEVERE</strong></td>
<td>5</td>
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</table>

**Definition:**
- **None:** When tics are present, they do not interrupt the flow of behavior or speech.
- **Minimal:** When tics are present, they occasionally interrupt the flow of behavior or speech.
- **Mild:** When tics are present, they occasionally interrupt the flow of behavior or speech.
- **Moderate:** When tics are present, they frequently interrupt the flow of behavior or speech.
- **Marked:** When tics are present, they frequently interrupt the flow of behavior or speech, and they occasionally disrupt intended action or communication.
- **Severe:** When tics are present, they frequently disrupt intended action or communication.
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<td></td>
<td></td>
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<td>30</td>
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- **NONE**: No tics are associated with any difficulties.
- **MINIMAL**: Tics associated with subtle difficulties in self-esteem, family life, social acceptance, or school or job functioning (infrequent upset or concern about tics vis a vis the future, periodic, slight increase in family tensions because of tics, friends or acquaintances may occasionally notice or comment about tics in an upsetting way).
- **MODERATE**: Tics associated with some clear problems in self-esteem family life, social acceptance, or school or job functioning (episodes of dysphoria, periodic distress and upheaval in the family, frequent teasing by peers or episodic social avoidance, periodic interference in school or job performance because of tics).
- **MARKED**: Tics associated with major difficulties in self-esteem, family life, social acceptance, or school or job functioning.
- **SEVERE**: Tics associated with extreme difficulties in self-esteem, family life, social acceptance, or school or job functioning (severe depression with suicidal ideation, disruption of the family (separation/divorce, residential placement), disruption of social tics - severely restricted life because of social stigma and social avoidance, removal from school or loss of job).
Appendix D: Urge ratings and manipulation check form

Participant #________

Date:________

Condition (Circle):  BL  DRO  RC

**Before the start of the condition:** How would you rate your overall level of urge to tic right now? _____

*Ask the child the following questions verbatim. Write down their response verbatim.*

What were the instructions I gave you for the last section?

Were you supposed to be trying to stop your tics during the last section?

Were you trying to stop your tics during the last section?

*For the RC condition only:*

How did you lose tokens?

*For the DRO condition only:*

How did you earn tokens?

*For all conditions:* How would you rate your overall level of urge to tic during the last 5 min?
Appendix E: Urge thermometer

0  Not at all
2  A little bit
4  A little bit
6  A lot
8  Very, very much
Appendix F: Instructions for experimental conditions

Before all conditions:

“This monitor in front of you is a tic detector. The tic detector can monitor movements and can count how many tics you have. You do not have to count your own tics because the tic detector will do that for us. Because the tic detector will be focused on you, it is really important that you do not leave your chair or turn away from the machine. Also, keep your hands in your lap or on the arms of the chair. Don’t put your hands over your face.”

Instructions for introduction/completing the “Stress Thermometer” (Adapted from the ADIS-4):

“Before and after each task you do, I will ask you to tell me how much you feel the urge to tic. To help you show us how you feel, we will use this picture of thermometers. Do you know what a thermometer does? Well, this urge thermometer works somewhat like a real thermometer does. If I had a real thermometer, I would put it in your mouth and it would measure your temperature, from very low to very high. Well, with this urge thermometer, we measure the urge you feel to tic, from not at all to very, very much, by pointing to the number on the thermometer that best shows how you feel.

At this point, explain the 9-point scale, from 0 (not at all) to 8 (very, very much), and demonstrate urge thermometer, explaining how the more “mercury” that appears means more feeling, that is, that “you have more of [insert] feeling, just like a regular thermometer. The interviewer then gives practice examples and ensures the child’s understanding of the scale.

“Okay, now that you understand how the thermometer measures the urge to tic, let’s practice with a few examples.”

1) Pretend that you have an itch in your arm and it is really bad. What number would you give it?
   a. Correct answer: >4

2) Pretend you have a funny feeling in your stomach, but you can barely feel it. What number would you give it?
   a. Correct answer: <3

3) Pretend that you have a pain in your eye, and it is so bad you can’t even open your eye. What number would you give it?
   a. Correct answer: 7-10

4) Pretend that you have a tickle in your foot. It is not too bad, but it is bugging you some. What number would you give it?
   a. Correct answer: 3-6

5) Pretend you that the muscles in your shoulder are tight, but you barely notice them unless you think about your shoulder really hard. What number would you give it?
   a. Correct answer: 0-3
   b. Correct answer: >5
Instructions for BASELINE:

“For the next 5 minutes we are going to have you just sit in this chair. The tic detector will be on, but try to ignore it and feel free to tic as much or as little as you need to. Stay seated in the chair with your hands in your lap or on the armrests.”

Let’s review. What do we want you to do for the next 5 minutes? I will be back in 5 minutes. Do you have any questions?”

First time any condition involving DRO occurs: Now let’s review the tics that you have so you know which ones the tic detector is counting. [review the child’s tics]. Good, now you know which tics you should try to stop. You can try to stop them any way that you want, except you can’t hold your face with your hands. Remember, because the tic detector will be focused on you, it is really important that you do not leave your chair or turn away from the machine. Also, keep your hands in your lap or on the arms of the chair. Remember, stay seated in the chair with your hands in your lap or on the armrests. I will be back in 5 minutes. Do you have any questions?”

Instructions for DRO condition:

“For the next 5 minutes, the tic detector will count your tics, and I want you to try your best to suppress your tics whatever way you know how. For each 10 second period you go without having tics you will earn a token.”

Do you understand the instructions? Are you supposed to try to stop your tics? How do you get a token? What happens if you have a tic?

Instructions for RC Condition:

“For the next 5 minutes, the tic detector will count your tics, and it will remove a token every time you tic. It will also sound a buzzer sound when you tic. At the end of the day, we will count your tokens and you will be able to exchange them for prizes. Depending upon how many tokens you get, you can earn the prizes we talked about earlier. Again, a token will be removed every time you tic a tic.

Do you understand the instructions? Are you supposed to try to stop your tics? How do you get a token? What happens if you have a tic? What is the math task that I want you to do?”
Appendix G: Independent variable evaluation form

Condition (circle one): Pre-Experiment

1. Did the investigator explain the function of the tic detector?
   YES
   NON
   N/A

2. Did the investigator explain the function of the Urge Thermometer?
   YES
   NON
   N/A

3. Did the investigator explain what the participant was to do during the condition?
   YES
   NON
   N/A

4. Did the participant accurately repeat the instructions for the condition (eventually)?
   YES
   NON
   N/A

5. Prior to the start of the condition did the investigator ask the level of urge?
   YES
   NON
   N/A

6. Did the investigator ask what were the prior instructions were for the previous condition?
   YES
   NON
   N/A

7. Did the investigator ask if the participant was supposed to be stopping their tics?
   YES
   NON
   N/A

8. Did the investigator ask if the participant was supposed to stop their tics in the previous condition?
   YES
   NON
   N/A

9. Did the investigator ask if the participant was trying to stop their tics in the previous condition?
   YES
   NON
   N/A
10. Did the investigator ask how tokens were lost during the previous condition?

YES\/NON/A

11. Did the investigator ask what the participant’s urge level was during the past 5 minutes of the condition?

YES\/NON/A
Appendix H: IRB approval letter

February 6, 2013

Bryan Brandt
ABA-Applied Behavior Analysis
16329 Enclave Village Dr.
Tampa, FL 33647

RE: **Full Board Approval** for Initial Application

IRB#: Pro00009796
Title: Developing Stimulus Control Over Tics: An Examination of Aversive Covert Antecedents
Study Approval Period: 12/14/2012 to 12/14/2013

Dear Mr. Brandt,

On 12/14/2012 the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents outlined below. Please note that your approval for this study will expire on 12/14/2013.

Approved Items:
Protocol Document(s):
Masters Thesis Proposal

Consent/Assent Document(s)
Child Assent 12-18.pdf 2/6/2013 8:44 AM 0.01
Parental Permission.pdf 2/6/2013 8:44 AM 0.01

Please note, if applicable, the informed consent/assent documents are valid during the period indicated by the official, IRB-Approval stamp located on the form. You are to use only the watermarked/stamped consent forms found under the “Attachment Tab” in the recruitment of participants. Make copies from the original.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.
We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

[Signature]

John Schinka, PhD, Chairperson
USF Institutional Review Board