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Is There a Relationship Between Tic Frequency and Physiological Arousal? Examination in a Sample of Children with Co-Occurring Tic and Anxiety Disorders

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Abstract

Stress is the contextual variable most commonly implicated in tic exacerbations. However, research examining associations between tics, stressors, and the biological stress response has yielded mixed results. This study examined whether tics occur at a greater frequency during discrete periods of heightened physiological arousal. Children with co-occurring tic and anxiety disorders (n = 8) completed two stress induction tasks (discussion of family conflict, public speech). Observational (tic frequencies) and physiological (heart rate) data were synchronized using The Observer XT, and tic frequencies were compared across periods of high and low heart rate. Tic frequencies across the entire experiment did not increase during periods of higher heart rate. During the speech task, tic frequencies were significantly lower during periods of higher heart rate. Results suggest that tic exacerbations may not be associated with heightened physiological arousal and highlight the need for further tic research using integrated measurement of behavioral and biological processes.

Keywords

Tourette; tic; stress; physiology; children; anxiety

Chronic tic disorders (CTD) are childhood-onset neuropsychiatric conditions characterized by the presence of tics, which are sudden, rapid, recurrent, stereotyped motor movements or vocalizations that are often preceded by aversive premonitory urges (American Psychiatric

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Association, 2013). CTDs, including Provisional Tic Disorder (previously referred to as Transient Tic Disorder), Persistent Motor or Vocal Tic Disorder (previously referred to as Chronic Motor or Vocal tic disorder;), and Tourette Disorder (TD), affect 0.8%–3% of children (Knight et al., 2012) and commonly co-occur with Obsessive-Compulsive Disorder (OCD), Attention Deficit Hyperactivity Disorder (ADHD), major depression, and other anxiety disorders (Kurlan et al., 2002).

A common feature of CTD is the fluctuation of tic frequencies across time, which is thought to be attributable in part to the influence of contextual variables (Conelea & Woods, 2008; Hoekstra, Dietrich, Edwards, Elamin, & Martino, 2012). “Contextual variables” are environmental stimuli or events that can have an immediate and direct impact on tic occurrence. Examples of contextual variables include the presence of particular stimuli, participation in certain tasks, or emotional reactions to specific activities or settings. Clarifying the role of specific contextual variables in tic expression and their mechanism of action is needed to increase the understanding of CTD pathology and to inform treatment development efforts.

The contextual variable most commonly implicated in short-term tic exacerbation is stress. Stress refers to any perturbation that disrupts an organism’s homeostasis (de Kloet, Joels, & Holsboer, 2005; Johnson, Kamilaris, Chrousos, & Gold, 1992). Stress impacts the organism by triggering behavioral, biochemical, and physiological changes aimed at maintaining or reinstating homeostasis (Johnson et al., 1992). In the CTD literature, the term “stress” has been used to refer to the stimuli that elicit the stress response (i.e., “stressors”), the perceived intensity or frequency of stress, and the biological markers of the stress response. Therefore, before outlining the research in this area, it is important to acknowledge that “stress” is a multifaceted term, and that the extent to which stress data across studies are comparable is not entirely clear.

The link between tics and stress has its origins in early anecdotal case reports (Clark, 1966; Dunlap, 1960). More recent data from self-report studies indicate that the majority of children and adults with CTD *perceive* tic worsening in association with stress, particularly stress due to minor life events and day-to-day hassles (Findley et al., 2003; Hoekstra et al., 2012; Steinberg, Shmuel-Baruch, Horesh, & Apter, 2012). Researchers have attempted to assess the accuracy of this perceived relationship by examining whether tic expression is associated with 1) stress-producing stimuli or tasks (“stressors”) and 2) biological markers of the stress response.

Research examining the impact of stressors on tic expression has yielded mixed results. Longitudinal research has demonstrated that self-reported psychosocial stress predicts future, short-term global tic severity (Lin et al., 2007; Lin et al., 2010). Tic changes during shorter and discrete time intervals have been reported in association with thermal stress and exercise challenges (Lombroso, Mack, Scahill, King, & Leckman, 1991; Scahill et al., 2001), movie clips eliciting stress-related emotional responses (Wood et al., 2003), and timed mental arithmetic (Conelea, Woods, & Brandt, 2011; Lees, Robertson, Trimble, & Murray, 1984). However, the direction of change in tic frequencies was variable both within and across these studies. For example, Scahill et al. (2001) and Lees et al. (1984) found that tic frequencies increased for some participants (50% in Scahill et al., 11% in Lees et al.) and were lower or unchanged for others (50% in Scahill et al., 13% Lees et al.). Conelea et al. (2011) and Wood et al. (2003) found that tic frequencies during stress-related conditions were generally the same or lower as compared to baseline. An additional experimental manipulation in the Conelea et al. (2011) study indicated that stress may disrupt tic suppression efforts, suggesting that self-reported “increases” in tics may actually reflect decreased tic suppressability.

Studies examining the relationship between tics and biological markers of the stress response have also yielded mixed findings. Several studies have shown that individuals with CTDs show a heightened biochemical response to stress-producing stimuli as compared to normal controls (Chappell et al., 1996; Chappell et al., 1994; Corbett, Mendoza, Baym, Bunge, & Levine, 2008). However, it is unclear if heightened stress reactivity is specifically associated with changes in tic frequency. A few studies have found significant and positive correlations between global ratings of tic severity (i.e., scores on the Yale Global Tic Severity Scale, Leckman et al., 1989) and markers of the physiological stress response, including morning salivary cortisol levels (Corbett et al., 2008) and levels of urinary norepinephrine excretion before and after a lumbar puncture stress task (Chappell et al., 1994).

Other studies have found nonsignificant or negative relationships between physiological markers of stress and tics. Chappell et al. (1996) found that tic severity was not significantly correlated with corticotrophin-releasing factor concentrations in lumbar cerebrospinal fluid. Corbett et al. (2008) found negative correlations between tic severity and both evening salivary cortisol levels and cortisol levels during the anticipatory phase of a mock magnetic resonance imaging (MRI) scan stress task. Based on this finding, the authors concluded that tics may serve an anxiolytic function, such that tic frequencies may increase during periods of stress in order to reduce anxiety. However, discrete changes in tic frequencies during the course of the stress task were not measured. One study did attempt to measure discrete fluctuations in tic frequency (Wood et al., 2003) and failed to find a systematic relationship between heart or respiratory rate and tic severity. Interestingly, Wood et al. (2003) noted discrepancies between self-report and objective tic changes in response to certain emotions —while participants reported that tics worsen in response to intense emotions, tics were actually lower in these conditions than baseline. The authors speculated that people may inaccurately monitor tics when experiencing intense emotions but become more aware of tics later, when tics have returned to baseline levels.

Taken together, the current literature indicates that some types of specific stressors may precede changes in tic expression for some, but not all, people with CTDs, suggesting idiographic variations in the stress-tic relationship. The literature also clearly indicates that those with tics experience heightened stress reactivity, but it remains unclear if tic frequencies increase during periods of heightened physiological arousal, as some have suggested (Corbett et al., 2008). Limitations of existing research include the narrow variety of stressors examined (e.g., thermal stress, mock MRI, timed mental math) and the paucity of direct observation to objectively measure moment-to-moment changes in tic frequency and physiological arousal simultaneously. Research incorporating direct observation, physiological measurement, and stressors with better generalizability is needed to help clarify the nature of the stress-tic relationship.

The current study aimed to examine the relationship between tic frequencies and physiological arousal during two stress induction tasks designed to have external validity in terms of similarity to day-to-day stressors encountered by children. The first task involved a discussion of family conflicts and the second task consisted of a public-speaking activity, which was derived from the Trier Social Stress Test (Buske-Kirschbaum et al., 1997). Based on research suggesting idiographic variability, we sought to examine the relationship between tic frequencies and physiological arousal at both the group and individual levels. It was hypothesized that tic frequencies would be greater during periods of heightened physiological arousal in group analyses, and that there would be variability in this pattern at the individual level.

Methods

Participants

Participants were a subsample of children who completed a study examining child reactivity, regulation, and parent-child interactive behavior in children with anxiety disorders. Children were eligible for the larger study if they 1) were between the ages 8–12, 2) lived with a primary caretaker, 3) and spoke English fluently. Exclusion criteria were: 1) cognitive delay, as indicated by an IQ score <70 based on parent report of psychological testing results, and 2) previous diagnosis of an autism spectrum disorder or psychotic disorder. In addition to these general criteria, children had to also meet specific inclusion criteria for one of three study groups. The anxiety group included children who met full DSM-IV-TR (APA, 2000) criteria for primary Separation Anxiety Disorder, Social Phobia, Generalized Anxiety Disorder, Specific Phobia, or Panic Disorder (operationalized as diagnosis with the highest severity rating on a structured clinical interview). The obsessive compulsive disorder (OCD) group included children who met full DSM-IV-TR criteria for primary OCD. Children in the anxiety and OCD groups could have comorbid anxiety or non-anxiety diagnoses. The nonclinical group included children who did not meet full DSM-IV-TR criteria for any disorder on the structured interview.

The current study was a subsample of 8 children from this larger study who also 1) met DSM-IV-TR criteria for Tourette Syndrome or Chronic Motor or Vocal Tic Disorder during the study diagnostic evaluation (n = 21 of 240 in the larger study); 2) had at least 1 discernable tic per minute, as observed on the videotape of the study's experimental session (n = 11 of those meeting criterion 1); and 3) had complete physiological data (n = 8 of those meeting criteria 1 and 2; those excluded had all or most data missing due to equipment problems). None of the included participants had current or prior history of psychiatric medication use. Participant age and diagnostic status are presented in Table 1.

Materials

Anxiety Disorders Interview Schedule for Children- Fourth Edition (ADIS-C; Silverman & Albano, 1995)—The ADIS-C is a structured, clinician-rated diagnostic interview administered to the parent and youth (ages 7–17 years) that yields DSM-IV-TR diagnoses for all anxiety, mood, and externalizing disorders and screens for additional disorders (e.g., psychosis, pervasive developmental disorders).

Video recorded observation—Participants were overtly video recorded during all experimental conditions. Tic frequency data coding and reliability procedures are described in detail below.

Physiological measurement—Heart rate (HR) was collected using a James Long Co. integrated psychophysiological assessment system. The computer algorithm that captures physiological data is time stamped, such that it can be synchronized with the second-by-second coding of the videotaped behavioral interaction. All physiological data was measured continuously during the stress induction tasks.

Procedures

The study was approved by the Rhode Island Hospital Institutional Review Board. Written informed consent from the parent/legal guardian and written assent from the child were obtained prior to study administration.

Assessment—Each participant and his/her parent(s) completed an initial diagnostic assessment using the ADIS-C. The ADIS-C was administered by bachelor's level psychology trainees who were trained in ADIS-C administration and supervised by a licensed clinical psychologist (A.G.). ADIS-C administrations were videotaped for interviewer reliability purposes. All raters achieved Kappa > 0.80 on all ADIS diagnoses during the training period, after which their reliability was spot checked by tape review. All raters remained at the Kappa > 0.80 criterion.

Stress induction tasks—Families completed the stress-induction tasks within 14 days of the assessment visit. All stress induction tasks were administered by a research assistant who was blind to the child's diagnostic status.

The first task was a parent-child "discussion task" (modeled after Siqueland, Kendall, & Steinberg, 1996 and Whaley, Pinto, & Sigman, 1999). The parent and child engaged in two, 5 minute conversations. In the "conflict conversation," families talked about something they frequently argue or fight about. The specific topic was identified by parent-report of the most prevalent and contentious topic from the Issues Checklist (Robin & Weiss, 1980). In the "anxiety conversation," families talked about something that makes the child worried or anxious; this topic area was identified by parent response to a question about the situation that makes the child most anxious. Only the parent and child were present in the room during this task.

The second task was a public speaking "speech task" (part of the Trier Social Stress Test for Children, Buske-Kirschbaum et al., 1997, and adapted from Ewart & Kolodner, 1991). Children were given the beginning of a story and asked to finish telling it for 5 minutes in as exciting a manner as possible in front of a committee of three adults, one of whom was their parent. Children were given 5 minutes to plan the speech and told to try to perform better than all the other children in this study. If children finished the story in less than 5 minutes, they were asked to continue. Audience members other than the parent (i.e., an unfamiliar research assistant) provided neutral feedback and kept a neutral facial expression during the child's speech.

A 5 minute baseline period occurred before and after each task. During this period, the child was left in the observation room by themselves and instructed to relax. Debriefing occurred after the last task and involved telling the child that they performed as well as other participants.

Tic frequency data coding—Tic frequency data were coded using The Observer XT 11.0 (Noldus Information Technology), a software program allows for precise coding of behavior frequency and duration and synchronization of behavioral coding data with physiological data. Videos and physiological data were imported into The Observer. Videos were then watched by trained coders and coded (by a time-stamped key stroke) for frequency of tics and duration of time that the child was fully visible in the video frame ("on camera").

Standard tic coding procedures were followed (Himle et al., 2006) to establish operational definitions for each child's tics and inter-rater reliability. It was not feasible to blind raters to experimental conditions given the need for coders to both see and hear participants on the videos (i.e., to code motor and vocal tics). However, coders were blind to study hypotheses. Operational definitions for each tic were developed collaboratively by the primary and secondary coders based on videotape observation and information recorded in the ADIS-C. If suspected tics were observed in the video that were not indicated in the assessment data, a third trained coder independently watched the tape in question and was asked to identify all tics observed. The suspected tic was included in frequency scoring if noted by the third rater. The secondary coder independently scored 100% of the videotapes for interrater agreement using the frequency-within-interval method of agreement (Himle et al., 2006). Interrater agreement was acceptable and similar to other tic observation studies (76.6%, range = 67–90%).

Data scoring—The Observer software was used for descriptive analyses of tic frequency and heart rate (HR) data. The Observer software allows the researcher to select specific intervals for analysis based on external data values (see example screen shot, Figure 1). This feature was used to identify intervals in which each child's HR was above or below his/her individual overall mean HR across the entire duration of the experiment (individual HR mean values are presented in Table 1). Tic frequencies, represented as a "tics per minute" (TPM) score, were first calculated in The Observer for all intervals in which the child's HR was above his/her mean (HR High) and the child was "on camera." Next, TPM scores were calculated for all intervals in which HR was below his/her mean (HR Low) and the child was "on camera." This process yielded two scores for each participant: 1) TPM during HR High intervals and 2) TPM during HR Low intervals. The duration of HR High and HR Low intervals was also calculated for each participant.

Next, the video was divided into two segments representing the separate phases of each stress task (discussion = pre-discussion baseline, discussion, post-discussion-baseline; speech = pre-speech baseline, speech, post-speech baseline). Using the same process, TPM scores during HR High intervals and HR Low intervals were calculated separately for the discussion and speech tasks to allow for comparisons between these topographically different stressors.

Descriptive data were then exported to SPSS (Version 19) for further analysis. Descriptive analyses revealed elevated values of skewness and kurtosis for some variables (i.e., HR Low: skewness = −.14, kurtosis = −1.05; interval duration of HR High: skewness = −.20, kurtosis = −2.06; interval duration of HR Low: skewness = −1.42, kurtosis = 2.17). Because data did not meet normality assumptions, two-tailed Wilcoxon signed-rank tests were used to compare TPM scores across HR High and HR Low intervals at the group level. Individual data patterns were examined graphically and analyzed visually.

Results

Tic frequencies across entire experiment

TPM scores during HR Low (M = 6.72, range = 2.63–9.59) and HR High (M = 7.01, range = 2.15–11.19) intervals did not significantly differ, T = 14, Z = −0.56, p = .58, r = −.19. The duration of HR Low (M = 23.15 min, range = 9.47–27.47 min) intervals was not different from the duration of HR High (M = 21.95 min, range = 18.41–24.36 min) intervals, T = 14, Z = −0.56, p = .58, r = −.19.

Results for each stress task

To determine if overall tic frequencies differed by stress task, TPM scores were first compared across the discussion and speech tasks. TPM did not significantly differ between the discussion (M = 6.99, range = 2.49–9.93) and speech (M = 5.84, range = 2.32–11.65) tasks, T = 11, Z = −0.98, p = .33, r = −.34.

Tic frequencies during discussion task

Discussion task TPM scores during HR Low (M = 7.47, range = 2.68–12.00) and HR High (M = 7.69, range = 2.35–11.40) intervals did not significantly differ, T = 14, Z = −0.56, p = .58, r = −.19. During the discussion task, the duration of HR Low (M = 13.37 min, range = 5.12–18.27 min) intervals was not different from the duration of HR High (M = 13.51 min, range = 6.99–14.79 min) intervals, T = 15, Z = −0.42, p = .67, r = −.24.

Tic frequencies during speech task

Mean speech task TPM scores were significantly lower during HR High (M = 5.50, range = 1.66–11.32) intervals than during HR Low (M = 6.64, range = 2.62–12.16) intervals, T = 1, Z = −2.38, p = .02, r = −.84. During the speech task, the duration of HR Low (M = 9.70 min, range = 4.10–13.02 min) intervals was not different from the duration of HR High (M = 8.58 min, range = 5.86–13.52 min) intervals, T = 16, Z = −0.28, p = .78, r = −.09.

Tic frequencies: Individual patterns

Individual TPM scores during HR High and HR Low across the entire experiment are presented in Figure 2. TPM scores appeared to be somewhat higher during HR High intervals for 4 participants (2, 5, 7, 8). Individual TPM scores for the discussion task are presented in Figure 3. Four participants appeared to have somewhat higher TPM scores during HR High intervals (2, 4, 5, 8). TPM scores for the speech task are in Figure 4; tic frequencies in HR High appeared lower or equal to HR Low intervals across all participants.

Discussion

Anecdotal and self-report research has long implicated stress as a contextual factor responsible for exacerbations in tic frequency. However, research incorporating objective measurement of tic frequencies and the biological stress response increasingly suggests that the stress-tic relationship may be different or more complex than originally thought. The current study examined whether tics occurred at a greater frequency during periods of heightened physiological arousal (HR High) as compared to periods of lower arousal (HR Low).

Contrary to our hypothesis, results showed that tic frequencies, as counted across the entire experiment, did not increase during periods of higher heart rate (HR High = HR Low). Interestingly, when tic frequencies were calculated separately for each stress induction task, tic frequencies were found to be *lower* during periods of higher heart rate (HR High < HR Low) during the speech task. Results did not appear to be influenced by the duration of intervals selected (i.e., time in HR High = time in HR Low) or by a differential tic frequency during each stress task (i.e., TPM in speech task = TPM in discussion task). Some individual variability was observed when tic frequencies over the course of the entire experiment and the discussion task were examined, such that half of the participants appeared to have slightly higher tic frequencies during HR High intervals. However, all participants showed the same pattern of equal or lower tic frequencies during HR High intervals of the speech task.

The finding that tic frequencies were equivalent or lower during periods of heightened physiological arousal is consistent with prior direct observation research showing that tics do not surpass baseline levels in response to stressors (e.g., Conelea et al., 2011, Wood et al., 2003). Results did not support the anxiolytic hypothesis proposed by Corbett et al. (2008); however, results between the two studies are notably consistent. Both studies found an inverse relationship between tic expression and biomarkers of stress (i.e., tics decrease as stress increases). Behavioral and biological explanations for this inverse relationship warrant further exploration in future research.

The results of the current study also add further evidence that self-reported perceptions of tic increases due to stress may be inaccurate. It is possible that other dimensions of tics not measured in the current study (e.g., tic or premonitory urge intensity) do change during periods of stress. It is also possible that awareness of tics increases in the presence of stressors, particularly those involving social situations, or that tic suppression becomes more difficult (Conelea et al., 2011). Furthermore, it is important to note that any one contextual factor, including “stress” or specific “stressors,” does not occur in isolation of other contextual factors (e.g., setting/place, presence of others, performance demands). Stress may co-occur with other contextual factors that do have a systematic impact on tics but have yet to be precisely identified. Therefore, there may indeed be phenomenological changes in the presence of stressors, but the nature and cause of this change may be more nuanced or difficult to discriminate by the individual with tics. It is imperative that the association between tics and stress continue to be examined using objective measurement rather than relying exclusively on self-report or even on clinician-rated severity measures that are based largely on patient report of global symptoms, such as the YGTSS.

Of note, the use of The Observer program in this study as a measurement method is new to CTD research. The capabilities of this research tool to integrate observational and physiological data are ideally suited to tic research, both in terms of research focused on the stress-tic relationship and on research examining the impact of contextual factors on tics more globally. In addition to heart rate, the program is capable of combining observational data with a wide range of data streams, including respiratory rate, eye tracking, EEG, and ECG (Zimmerman, Bolhuis, Willemsen, Meyer, & Noldus, 2009). Multimodal research incorporating tic frequency data with biological data is likely to contribute greatly to our understanding of brain-context-behavior relationships in CTDs.

The current study has several limitations, including sample characteristics and methodological issues. The study had a small sample, which unfortunately is typical of most research examining the stress-tic relationship (e.g., Chappell et al., 1996, Conelea et al., 2011; Corbett et al., 2008, Scahill et al., 2001, Wood et al., 2003). The sample was a subset of a larger study of children with primary anxiety disorders; therefore, all participants had co-occurring anxiety disorders and none had a primary tic disorder diagnosis. It is possible that the tic frequency patterns observed in the current study are influenced by the presence of heightened anxiety. However, it is worth noting that similar patterns (i.e., lower tic frequencies during stress conditions) have been observed in direct observation research with more “pure” CTD samples (e.g., Conelea et al., 2011, Wood et al., 2003). Future research using direct observation and physiological data in larger samples and those with primary CTD is needed to clarify the generalizability of current results and the possible moderating role of co-occurring psychopathology.

The larger study from which these data were drawn was not originally designed to specifically test the stress-tic relationship. Because of this, the study did not include measures typically administered in CTD research, most notably a tic severity measure. The experimental conditions did not tightly control for the presence of contextual factors known to influence tic frequencies in some children (Piacentini et al., 2006), including overt videotaping and the presence of other people. It is possible that the finding of lower tics during High HR intervals of the speech task in part reflects the nature of the task: children may have been more likely to actively try to suppress tics during this performance situation. Although the social elements of the stress tasks may have independently influenced results, the “real world” generalizability of these tasks is a strength of the current study, as previous research has tended to rely on stress induction tasks that are contrived (e.g., timed mental math; Conelea et al., 2011) or less commonly encountered by children (e.g., mock MRI, Corbett et al., 2008). Future research balancing methodological control with generalizability would improve our understanding of how stress may or may not influence tic frequencies in the context of realistic, day-to-day stressors. To this end, future research should consider strategies such as idiographic matching of stressors in a laboratory setting (e.g., bring child's actual perceived stressor into the lab) or recording of physiological arousal and tic changes in naturalistic settings (e.g., non-invasive data collection while child is at home or school).

Finally, heart rate was the only psychophysiological data collected. It is possible that tic frequencies are more closely related to different biological markers of the stress response, such as skin conductance. It may also be the case that the influence of stressors on tic frequencies may not be detectable within discrete intervals. For example, heightened heart rate may have a delayed impact on tic frequencies, or gradual fluctuations in tic frequencies over the course of a day or a week may correspond to gradual changes in physiological arousal, such as diurnal cortisol levels, as some have suggested (Corbett et al., 2008). Incorporating direct observation methods in research examining changes in physiological arousal over longer periods of time would help determine if this relationship exists.

In summary, this study adds to growing body of literature suggesting that the stress-tic relationship may not be as clear as once assumed. In the broad tic disorder literature, the role of stressors in exacerbating tics is often stated as fact (e.g., (Cohen, Leckman, & Bloch, 2012; Du et al., 2010; Roessner et al., 2013). Data from this and other small studies suggest that tic frequencies may not change during acute periods of stress or may change in counterintuitive ways, such as decrease rather than increase. Although these studies each carry limitations, they collectively suggest that researchers should more closely examine the behavioral and biological complexities of the stress-tic relationship rather than continue to assume that this relationship is unidirectional and universal. Future research addressing these complexities is likely to contribute to our understanding of how context impacts symptom expression in CTDs and may point to novel intervention strategies.

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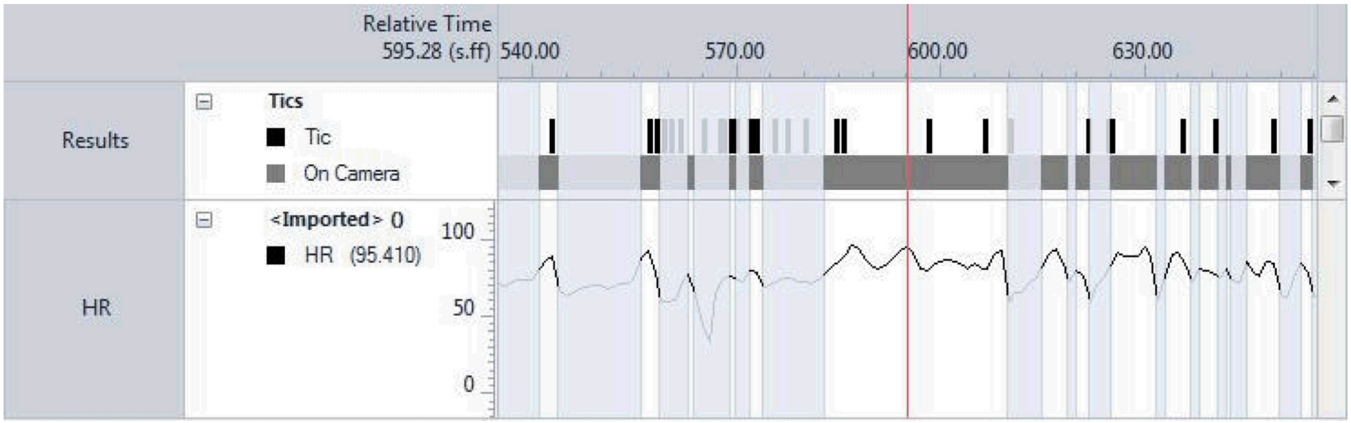

Figure 1.

Screen shot from The Observer XT showing visualization of coded data. Tics, visibility of child in camera frame, and heart rate (HR) are plotted horizontally against an axis representing elapsed time. In this screen shot, intervals in which HR is above the child's mean HR (HR High) are selected for analysis, as indicated by the "graying out" of non-selected periods in which HR is low.

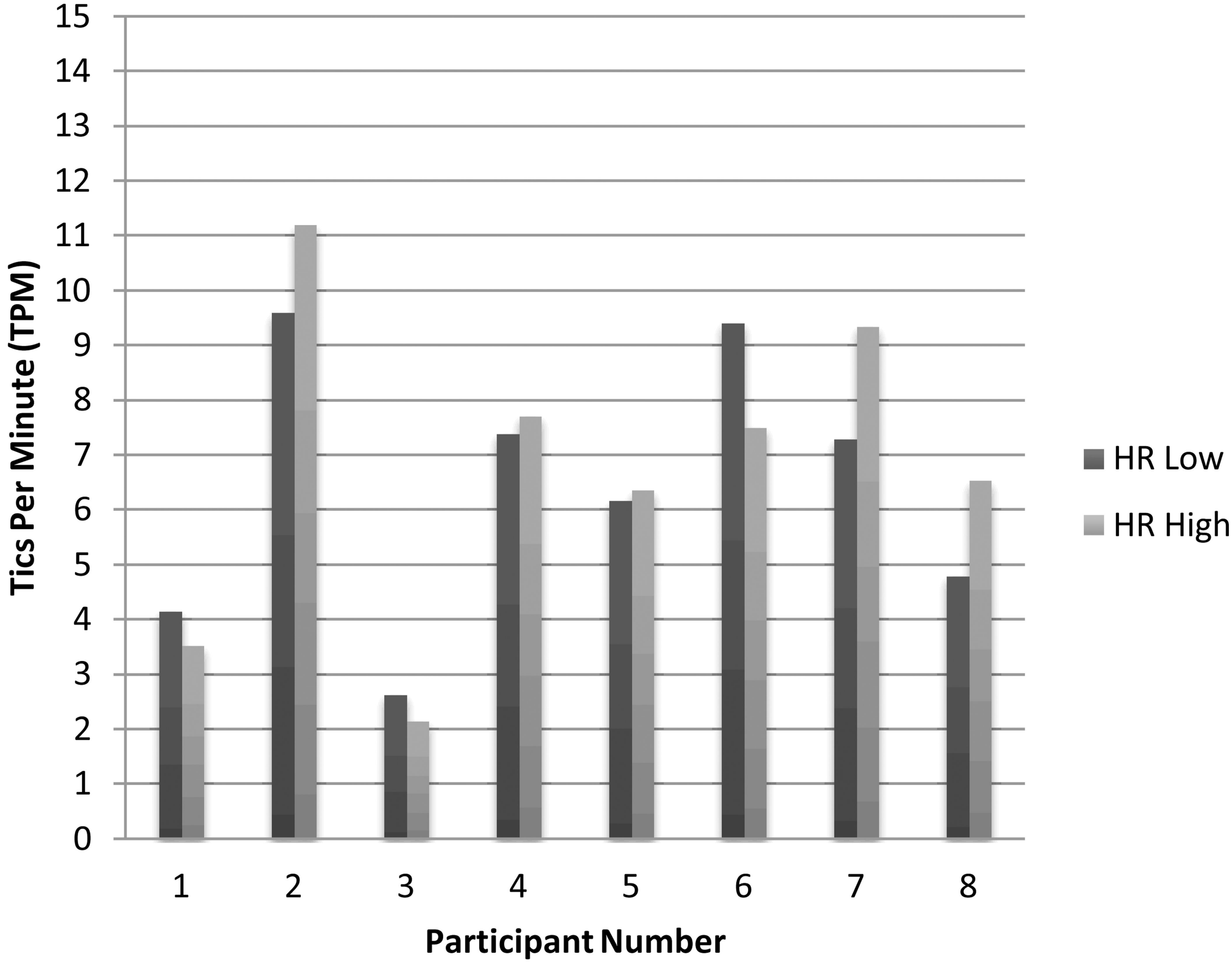

Figure 2.

Tics per minute (TPM) scores for individual participants across intervals in which heart rate (HR) was low (HR Low) and high (HR High) during the entire experiment.

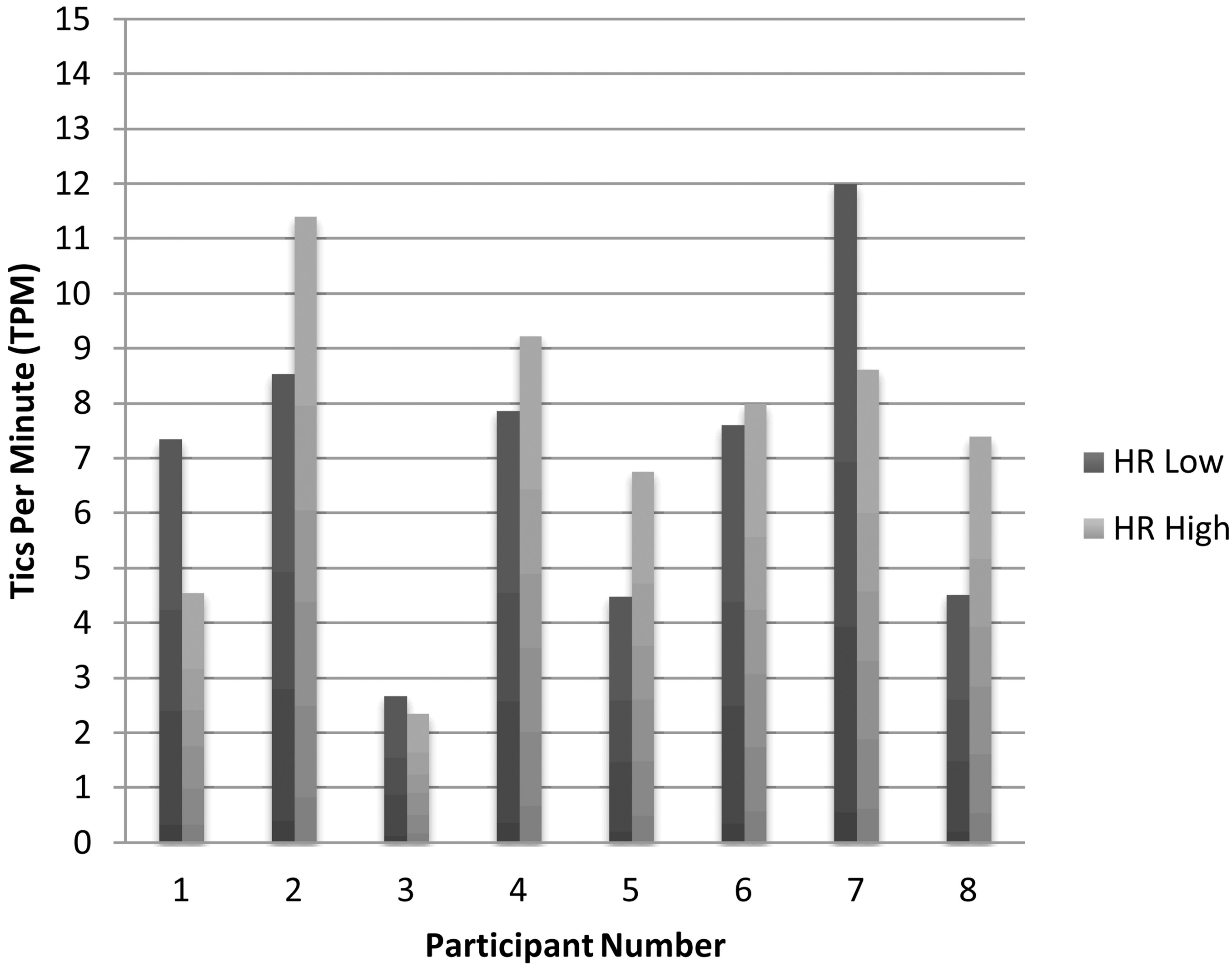

Figure 3.

Tics per minute (TPM) scores for individual participants across intervals in which heart rate (HR) was low (HR Low) and high (HR High) during the discussion task.

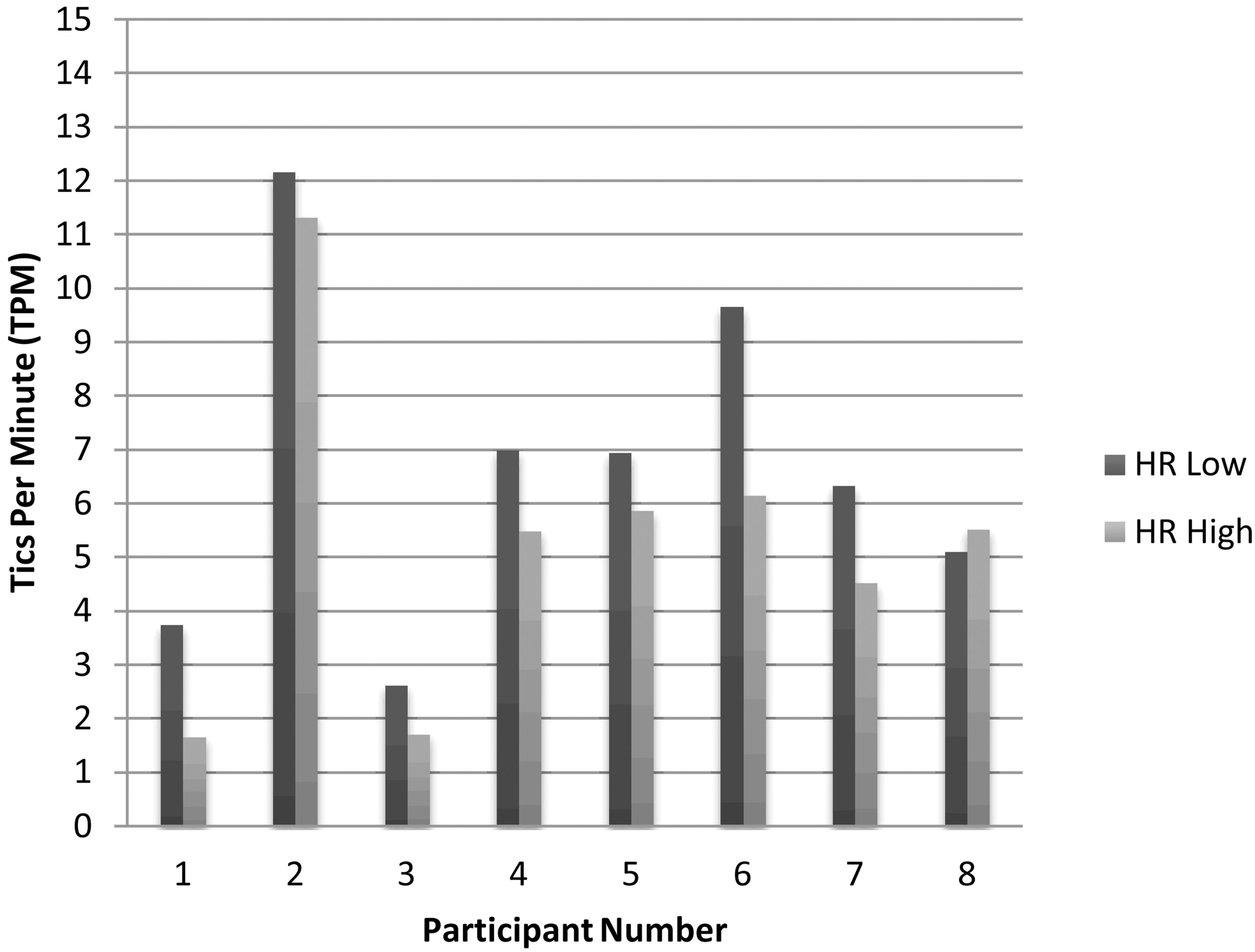

Figure 4.

Tics per minute (TPM) scores for individual participants across intervals in which heart rate (HR) was low (HR Low) and high (HR High) during the speech task.

Table 1

Participant Demographics and Individual Mean Heart Rate Values.

Participant Number	Age	Sex	Tic Diagnosis	Other ADIS-C Diagnoses	Heart Rate (mean, range)
1	11	F	TS	OCD, Panic Disorder, Oppositional Defiant Disorder	88.14 (63.08–116.07)
2	9	M	TS	Specific Phobia, Major Depressive Disorder, ADHD	81.73 (55.51–148.70)
3	8	M	CMTD	OCD, Generalized Anxiety Disorder, Social Anxiety Disorder, Separation Anxiety Disorder	88.40 (62.24–119.00)
4	12	M	TS	Specific Phobia	75.38 (50.25 – 102.80)
5	10	M	TS	Generalized Anxiety Disorder, Social Anxiety Disorder, OCD, Specific Phobia	87.22 (51.62 – 147.80)
6	8	M	CMTD	Anxiety Not Otherwise Specified	83.83 (51.85–121.25)
7	8	F	TS	OCD, Separation Anxiety Disorder, Generalized Anxiety Disorder	90.98 (52.37–174.77)
8	9	F	TS	OCD, Generalized Anxiety Disorder	95.42 (56.92–150.82)

Note. ADIS-C = Anxiety Disorders Interview Schedule for Children-Fourth Edition, TS = Tourette Syndrome, CMTD = chronic motor tic disorder, OCD = obsessive-compulsive disorder