Tics and Emotions

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Tics can be associated with neurological disorders and are thought to be the result of dysfunctional basal ganglia pathways. In Tourette Syndrome (TS), excess dopamine in the striatum is thought to excite the thalamo-cortical circuits, producing tics. When external stressors activate the hypothalamic-pituitary-adrenal (HPA) axis, more dopamine is produced, furthering the excitation of tic-producing pathways. Emotional processing structures in the limbic are also activated during tics, providing further evidence of a possible emotional component in motor ticking behaviors.

Keywords: tics ; emotions ; Basal ganglia ; Tourette's syndrome ; dopamine ; HPA-axis ; Premontory sensory phenomena

1. Introduction

Tics are phenomena or symptoms associated with dysfunction in the pathways of the basal ganglia, which are largely of childhood-onset. While many symptoms such as tremors and spasms are all concerned with basal ganglia dysfunction and can look similar to ticking, it is important to provide a specific definition. Tics can be characterized by premonitory urges, or premonitory sensory phenomena (PSP) that encompass a variety of sensations, including focal tension, burning, and itching [1]. Many individuals have reported that these urges are worse than the tics themselves and have stated that their tics are either a partial or fully voluntary response to PSP [2]. Additionally, tics are not task-specific, while other conditions such as stuttering and dystonia include basal ganglia dysfunction; it is only when specific tasks are performed (e.g., talking and walking) that the behavior becomes relevant [3]. In other words, tics are associated with PSPs, and occur independently of any task. Additionally, stereotypies and tics can be mistaken for one another; there are characteristics that can clarify the differences between the two. Stereotypies have an average onset age of 3 years, while tics will typically emerge between 5–7 years old [4]. Additionally, stereotypies include constant and fixed movement patterns, rhythmic and prolonged or continuous movements, are not associated with premonitory urges, and can be suppressed with distractions [5]. Conversely, tics are associated with quick and sudden movements and the urge to tic is usually preceded by a premonitory urge(s) [4]. Tics are also most common in the eyes, head, and shoulders, while stereotypies usually occur in the mouth, hands, and arms, sometimes involving the whole body [4]. With the features of tics established, we will examine the role of the basal ganglia and its relationship to ticking behaviors, with an emphasis on the relationship between emotions and ticking behaviors.

The basal ganglia consists of a small yet complex group of subcortical nuclei located deep within the cerebral hemispheres at the base of the forebrain. The primary nuclei of the basal ganglia (the striatum, globus pallidus, subthalamic nucleus, and substantia nigra) are significant with regard to motor control, emotion, and cognition. It is imperative to examine the interconnections between these functions to better understand the nature of motor and verbal tics. The basal ganglia-cerebellar-thalamocortical system provides a mechanism for tic production and can also aid in comprehending the connection between emotions and tics.

The basal ganglia, cerebellum, and thalamus are a densely interconnected network that is thought to influence many of the same areas of the cerebral cortex. Two routes of information processing in this network have been demonstrated: the direct and the indirect pathways. In the direct pathway, medium spiny neurons (MSNs) in the striatum project directly to the output nuclei, which include the internal globus pallidus (GPi) and the substantia nigra pars reticulata (SNr). The indirect pathway takes a longer approach, where MSNs project onto the external globus pallidus (GPe), which then projects onto the GPi and SNr [6]. The GPe has also been observed to project to both the motor and non-motor regions of the dentate nucleus when rabies virus was injected into different spatial regions of the GPe of macaque monkeys, which resulted in transneuronal transport to neurons in the cerebellum [6][7]. Therefore, it can be concluded that cerebellar output targets medium spiny neurons in the indirect pathway of the basal ganglia-cerebellar-thalamo-cortical circuit [6]. This is an important finding, as abnormalities at one end of the network could spread throughout the entire system, affecting activity in other places along the pathway. Because the amygdala, hypothalamic-pituitary-adrenal (HPA) axis, and other aspects associated with emotions play into this network, it is thought that emotions can influence ticking behaviors.

It has been known for some time that emotional variables influence tic behavior. Bornstein and colleagues [8] reported that the majority of their participants (98.2 percent) related that anxiety or perceived stress exacerbated their tic behaviors. Their results were confirmed by Eapen and associates [9] and by Silva and colleagues [10]. Findley and associates [11] provided additional support for the relation between stressful life events and tics. They noted that, in 32 children with TS and OCD, significantly greater stressful life events were reported compared with matched controls. Hoekstra and associates [12], in a longitudinal study, found significant correlations between negative life events and tic severity. O'Connor et al. [13][14] found that frustration was an emotional state that was mostly related with high-risk and ticking behaviors. The literature generally supports the notion that anxiety, stressors, and frustration are significantly related to increases in the frequency and intensity of tic behavior, with a review of significant findings reported by Conelea and Woods [15].

Tourette syndrome (TS) is the most commonly diagnosed tic disorder, but not every tic disorder is indicative of TS. Many tic disorders use similar pathways in the basal ganglia circuitry to produce ticking behaviors, but the presence of tics should not result in an immediate assumption of TS. In TS, tics are associated with abnormalities in the basal ganglia, particularly with the striatal GABAergic networks, leading to an excess of striatal dopamine [16][17].

Changes in striatal dopamine release can induce tic production due to "a focal excitatory abnormality in the striatum that causes undesired disinhibition of thalamocortical circuits, whose effect is the production of tics" [17]. When there is a further influx of dopamine to an already overabundant supply in the striatum, tic production can be exacerbated. For example, the HPA axis responds to acute stress by producing the corticotropin-releasing hormone (CRTH), which in turn promotes the release of the adrenocorticotropic hormone (ACTH) from the pituitary gland and cortisol from the adrenal cortex [18]. While these actions are essential for coping with stress, it is thought that they are mediated by dopamine release [18].

The emotional components of tics may also have an effect on immunity and health. HPA axis activation due to psychological stress can be evoked by infections and injuries, and it is suggested that the influence of stress on ticking behaviors is related to the influence of the immune system on tic expression [19]. Because dopamine is a major neurotransmitter that is vital to HPA axis activation, any changes in dopaminergic neurotransmission can have an effect on stress, tic expression, and immunity [19]. Martino et al. [19][20] developed a model that described how an "enhanced autoimmune response might contribute to the onset or worsening of tics via dopaminergic neurotransmission" [19][20]. This model explains that psychosocial stress can indirectly contribute to increased dopamine release from the sympathetic nervous system, which can lead to an enhanced autoimmune response [20]. Additionally, other studies observed that plasma dopamine levels increased with reports of stress: this is the primary source of dopamine for T-cells, which help regulate immune response [21].

2. Behavioral Aspects of Tics

Emotional states can involve the asymmetric activation of dopaminergic pathways, with hemispheric activation depending on the amount of time exposed to stress [22]. For example, while Parkinson's disease is not considered a tic disorder, it is still associated with basal ganglia dysfunction, and it was found that individuals with right-sided (left basal ganglia abnormalities) symptoms, compared to those with left-sided symptoms, were reported to experience more depressive symptoms [22]. Therefore, it is possible that, with regard to ticking behaviors, comorbid conditions could be an indication of hemispheric abnormalities in the basal ganglia that can produce ticking behaviors [23].

A variety of emotions can exacerbate ticking behaviors, including frustration, anger, and anxiety. Problems completing complex tasks due to ticking behaviors can lead to a level of frustration associated with the consequence and anticipation of the task performance, especially if the task involves controlled regulation [24] in open-loop systems. In open-loop or non-feedback-based systems, the control action from the controller is not constrained by the "process output", which is the process variable that is being controlled. It does not use feedback to govern its output depending on whether or not the desired goal is achieved.

It is possible that frustration can also impair a ticking individual's ability to plan actions using visuo-spatial cues, which could result in an over-reliance on somatosensory proprioception to know when an action has been accomplished. Because of this, the muscles are over-ready for action, leading to increased muscle tension. By definition, muscles must be tensed in order to tic: many people who report premonitory urges also report high overall muscle tension, based on self-reports [13][24]. Another study by O'Connor and colleagues found that tic onset is predominantly associated with dissatisfying and tension-producing activities, [13][25] thus confirming an association between frustration and tic onset.

A study by Cavanna et al. [26] confirmed that anger also plays a role in ticking behaviors. It was found that individuals with TS scored higher on the Conners' Parent Rating Scales-Revised (CPRS-R) and Conners' Teacher Rating Scales-Revised (CTRS-R), with "most scores falling within the 'borderline' and 'pathological' range for behavioral disorders" [26]. These individuals also scored higher on the Child Behavior Checklist (CBCL) compared to their neurotypical peers. While this study has a limited sample size, and the results should, therefore, be analyzed with caution, other investigations have supported Cavanna and associates' [26] conclusion that individuals with tic disorders tend to have higher instances of anger and aggression. A study conducted by Freeman [27] found that anger is considered to be a comorbid symptom of tic disorders, especially when ADHD is also present. In fact, it is thought that ADHD accounts for the anger and aggression commonly seen in TS individuals [27].

Anxiety is also thought to play a role in tic disorders, as confirmed by a study conducted by Coffey et al. [28]. General psychiatric comorbidity was overwhelmingly abundant in the 190-person sample size (100% in individuals classified as having severe tics, 94% in individuals classified as having moderate tics), including anxiety disorders. Anxiety disorders (with the exception of simple and social phobia) were severely overrepresented, including "panic disorder, agoraphobia, separation anxiety disorder, and overanxious disorder" [28]. It was observed that separation anxiety most strongly predicted tic severity, and presence of multiple anxiety disorders was thought to be associated with a 3.5× higher likelihood of severe ticking behavior [28]. Along the lines of separation anxiety described above, Dehning and colleagues found that TS individuals showed higher levels of attachment anxiety and attachment avoidance in their relationships, possibly due to maladaptive experiences in childhood [29]. Additionally, a case study of a 6 y/o boy was presented, in which he experienced multiple vocal and motor tics along with symptoms of anxiety related to separation from his mother [30]. However, after cognitive-behavioral therapy and attachment-focused therapeutics, tic frequency eventually decreased, highlighting the importance of addressing comorbid conditions associated with ticking disorders.

There are reports of stress-related fluctuations on tic severity, commonly occurring due to fatigue, emotional trauma, anxiety, and stress [31][32]. A stress response is initiated by the release of CRH from the hypothalamus, which then stimulates the synthesis and release of ACTH from the pituitary gland, which ultimately allows for the release of glucocorticoids (including cortisol) from the adrenal gland [31]. Cortisol is an important homeostatic regulator whose secretion follows a circadian rhythm, with levels being highest in the morning and lowest at night. One of the most widely-used biomarkers of stress is the circulating concentration of cortisol secreted by the adrenal gland, which plays a large role in the HPA axis and in the stress response. A study conducted by Corbett and colleagues [31] examined the diurnal cortisol pattern and reactivity of the HPA axis in children with TS. They found that children with TS displayed increased levels of anxiety across all levels on the Multidimensional Anxiety Scale for Children compared to typically developing children. Additionally, while there was no statistically significant difference in the morning and afternoon diurnal cortisol rhythm between the TS and control groups, it was noted that subjects with TS displayed lower levels of cortisol at night [31]. Because lower evening cortisol profiles are associated with chronic stress conditions [33][34][35], it is thought that these decreased levels in TS individuals could be the result of daily stress, possibly due to daily tic suppression. Additionally, when the participants' stress responses were tested by placing them in an MRI apparatus, children with TS showed increased cortisol levels in response to the MRI environment when compared to their neurotypical peers [31]. This supports a heightened level of responsiveness of the HPA axis in response to stress in children with TS [31].

With increased stress usually comes an increase in heart rate. TS individuals commonly report symptoms consistent with sympathetic nervous system overactivity, including increased heart rate, nervousness, and agitation [32][36]. A study performed by van Dijk and associates [37] found that, during a valsalva test, individuals with TS displayed a larger maximum (but not a minimum) heart rate compared to neurotypical controls, possibly due to the initial heart rate in this group of TS individuals being higher than the control group [36][37]. Additionally, in a study looking at cardiovascular and catecholaminergic activity during mental load, Tulen et al. [38] found enhanced cardiovascular activity in tic individuals, "with higher heart rate and blood pressure during baseline compared to healthy controls" [36][38].

Galvanic skin response (GSR) is another easy way to measure sympathetic autonomic nervous system activity and can reflect changes in peripheral autonomic arousal. A study conducted by Nagai and colleagues [39] observed how changes in sympathetic arousal (induced using GSR biofeedback) impact tic frequency in individuals with TS. The total number of tics was significantly lower during relaxation GSR biofeedback than during arousal GSR biofeedback, reflected in the frequency of facial and motor tics. In the arousal biofeedback condition, there was a significant correlation between GSR activity "and the number of tics at the start of the session such that higher sympathetic tone was associated with increased tic frequency across individuals" [39]. Therefore, it is hypothesized that GSR biofeedback training could help in the treatment of individuals with TS due to the observed lower tick frequency in the relaxation GSR biofeedback condition.

While the GSR is associated with a response to stress, it is also thought that perceived stress by individuals with tic disorders can influence ticking behavior. A study performed by Lin and colleagues [40] examined the relationship between psychosocial stress and tic fluctuations in children and adolescents with TS and/or OCD. Psychosocial stress was measured by a participant's self-report, parental report, and clinician ratings of long-term contextual threat.

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