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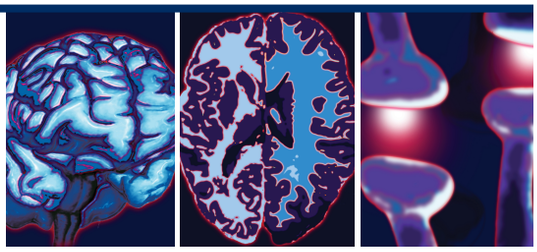

Bridging neuroscience and clinical psychology: cognitive behavioral and psychophysiological models in the evaluation and treatment of Gilles de la Tourette syndrome

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Practice points

- Gilles de la Tourette syndrome (GTS) is, by definition, a multidisciplinary challenge.
- Evaluation and treatment require integration of cognitive, behavioral, psychophysiological and neurobiological approaches.
- Brain plasticity in GTS suggests that treatment can have both behavioral and physiological consequences.
- Treatment could combine pharmacological, psychophysiological and behavioral interventions.
- Cognitive and metacognitive training in motor planning and inhibition can complement behavioral interventions in GTS.
- The addition of cognitive remediation to cognitive behavioral therapy may produce changes in electrocortical function post-therapy.
- Future research should explore the potential of psychophysiological therapies addressing specific processes in GTS.

SUMMARY Cognitive neuroscience and clinical psychology have long been considered to be separate disciplines. However, the phenomenon of brain plasticity in the context of a psychological intervention highlights the mechanisms of brain compensation and requires linking both clinical cognition and cognitive psychophysiology. A quantifiable normalization of brain activity seems to be correlated with an improvement of the tic symptoms after cognitive behavioral therapy in patients with Gilles de la Tourette syndrome (GTS). This article presents broad outlines of the state of the current literature in the field of GTS. We present our clinical research model and methodology for the integration of cognitive neuroscience in the psychological evaluation and treatment of GTS to manage chronic tic symptoms.

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Clinical presentation

■ Context & clinical description

In the revision of the DSM-IV, Gilles de la Tourette Syndrome (GTS) is classified under the tic disorder category within the disorders usually first diagnosed in infancy, childhood or adolescence [1]. The essential feature of GTS is the presence of at least two or more simple or complex tics including a vocal and motor tic. Hence, GTS is characterized by bouts of repetitive daily tics for at least 1 year and starting before the age of 18 years. Simple motor tics are induced by involuntary and repetitive contractions of skeletal muscles that are functionally related, leading to simple movements such as eye blinking, cheek clenching, jerky movements of the head and shoulder shrugs [2,3]. Complex motor tics are contractions of multiple muscular systems leading to complex and repetitive movements, such as hopping, body movements or object contacts, grimaces, abdominal spasms, taps, extensible movements from arms/legs, sequential movement of shoulders, copropraxia (i.e., performing involuntary and obscene gestures such as touching of a sexual nature on oneself or on others) or echokinesis (i.e., imitating gestures of others without being able to prevent them). Vocal tics can also be simple (e.g., coughing, sniffing and clearing throat) or complex (e.g., swearing, repeating sounds or phrases, and breathing convulsively).

■ Prevalence

Previously considered as a rare condition, the current estimate is that between 5 and 20% of the general population have, at some point in their life, presented with transitory or chronic tics [4]. This proportion varies from 6 to 28% among children with special care needs [5,6]. Recent epidemiological studies estimate a mean prevalence of 1% among children of school age varying between 0.03 and 2.99% [7,8–10].

Regardless of the population, GTS is four-times more frequent among boys than girls [9,11]. Although the number of studies on adults is very limited, the prevalence of GTS in this segment of the population was estimated at 2.2 per 1000 women and 7.7 per 1000 men [12].

A genetic transmission is considered to be central to GTS. In studies of monozygotic twins, individuals afflicted with GTS showed approximately 50–70% concordance for the illness, while dizygotic twins showed only 9% concordance. However, the genetic influence is not the only factor involved in GTS [13].

■ Developmental trajectory & the apparent decrease of tics

Symptom frequency and intensity are at their highest between the age of 10 and 12 years [10,14–16], followed by a progressive decrease during adolescence [17]. Close to a third of adults afflicted with GTS report almost no tics [18]. Nonetheless, among those who were afflicted during their childhood, 11% of adults continue to experience moderate-to-severe symptoms [14]. Among the latter, the chronic persistance of tics can become an important handicap linked mainly to the persistence of hyperkinesia, impulsivity, attention deficit and anxiety. Furthermore, these afflicted individuals are socially stigmatized [11,19]. Case studies have indicated that adult patients with GTS, compared with adults in the general population, show more dysfunction in their daily activities and a lower quality of life [20–22].

However, these assumptions about symptom evolution may need revision. Earlier results indicate that 90% of ex-GTS adults, who reported themselves to be without tics, were still affected according to a quantitative assessment, based on video observations [23]. It seems that the participants were not aware of these tic manifestations, because of the decrease in symptomatic intensity. Thus, the hypothesis of spontaneous remission of symptoms in adulthood seems to be an artifact attributed to acclimatization, or to a strategy of camouflage or inhibition developed by adults over time.

■ Multiple dimensions of GTS & concomitant symptoms

There is currently a debate regarding the DSM-V on the range of the obsessive-compulsive disorder (OCD) spectrum, which according to certain authors includes both tics and OCD. However, our research has brought us to consider that tic disorders are actually an entity independent of OCD [24], although GTS and OCD may appear together. Approximately half of children and adolescents with GTS have at least one concomitant disorder, the consequences of which more often interfere with daily life than the tic expression *per se*. The prognosis is less favorable in the presence of these concomitant disorders [11] and the family must frequently use specialized services among academic, medical or psychological professionals. Even if severe tics emerge as an important psychological and social disorder, an existing diagnosis of ADHD and OCD represent an important additional burden. The most disabling

symptoms for the child are those of ADHD, sleeping problems (e.g., insomnia, sleepwalking and periodic leg movements) and anger control [11]. A large international study stressed that ADHD is present in approximately 55% of children afflicted with GTS and represents the main associated disorder in this segment of the general population [25]. Among adults with GTS, OCD, anxiety and depression become the most prevalent symptoms. In more than 40% of adults with GTS and OCD [26], the most common compulsions were related to excessive washing, excessive verification and order [27].

Anger, opposition and aggressive behavior are present among approximately 50% of children with GTS [28]. Explosive outbursts, described as a violent anger crisis that occurs in a sudden and recurrent manner, are distinguished by their intensity and contextual profile. The reaction seems disproportionate in relation to the trigger and parents often consider these symptoms as the ones that interfere the most in the family as well as in the academic domain [29]. Explosive outbursts can be viewed as a form of emotional tic, hence they occur abruptly, sometimes intensively and seemingly without volition, and seem to be a behavioral result of the interplay between various comorbidities [29]. The impulsivity and lack of self-control related to ADHD, plus the perfectionism and cognitive rigidity related to OCD may result in an explosive mix [29].

■ Etiologies of GTS: a 3D model

The model of developmental & behavioral neuroplasticity

GTS is characterized by its fluctuating nature over time, and, as we have seen in the previous section, its developmental trajectory needs to be considered. Through longitudinal studies, certain hypotheses have underlined cerebral anomalies associated with the persistency of the symptoms in adulthood. Peterson and collaborators propose that because it is present in every age group, the hypometabolism of the caudate nucleus could constitute a feature of GTS [30]. Moreover, the decrease in volume of the putamen, the internal globus pallidus and prefrontal areas, as well as the increase in volume of premotor areas, are uniquely present among adults, which suggests that they are associated with specific pathological mechanisms contributing to the maintenance of symptoms among subgroups of adults with significant symptoms of GTS persisting during adulthood [31]. Among these individuals, there seems to be a failure of the cerebral plasticity mechanism that allows compensation for the presence of tics by overactivation of a motor inhibition process. Unlike adults, children with GTS have a larger orbitofrontal volume [32] and bilateral putamen [33,34], which would constitute an adaptive plasticity in response to the expression of tics, which, in turn, would help to inhibit them more easily. With the maturation of the prefrontal cortex during adolescence, this mechanism could gain strength and explain the symptom decrease during adolescence and early adulthood. Among adults with persistent symptoms, this prefrontal compensation could not occur entirely. The decrease in volume of the putamen and globus pallidus and thus the increase in volume of the premotor areas, could be secondary to this compensation after long-term experience of inhibiting these chronic tics.

These neurodevelopmental observations are compatible with cognitive behavioral therapy (CBT) and cognitive remediation models [35]. If the evolution and fluctuation of symptoms is related to a form of cerebral plasticity, we propose that CBT will, in turn, improve symptoms as well as favor neurophysiological changes corresponding to a normalization of cerebral function, a phenomenon that has recently been observed by our team [36,37].

Cognitive & behavioral observations

The presence of tics generates significant distress including phobias, depression, social anxiety, self-image concerns, a decrease in self-esteem, relationship problems [38], and negative perception of peers and the social rejection [19,39,40]. Also noticeable is a particular style of behavioral planning. Thus, preliminary results from responses on the style of planning (STOP) questionnaire [35] suggest that GTS can be defined by chronic overactivation, the difficulty of staying focused and the tendency to undertake many things at the same time (overactivity), as well as an increased investment in efforts related to motor function (overpreparation). Thus, overactivity is distinct from hyperactivity, although the two can be clinically confused. In fact, overactivity can be present in the absence of hyperactivity. These two components of planning action constitute the basic ingredients that are currently put forward in therapy and directly impact on neuroplasticity.

Environmental & psychosocial observations

Beyond the neurocognitive and behavioral origin of GTS, psychosocial observations are critical to

embrace the full picture of symptom evolution. First, environmental factors such as the presence of an academic support and the quality of social interactions can influence symptom severity [41]. Moreover, behavioral approaches conceptualize tic manifestations as being primarily associated with basic principles of learning and the management of environmental contingencies [42]. Within that perspective, tics are considered as an exaggerated response evolving as a social operant conditioning. Consequently, tic manifestation will be more frequent when the individual receives attention or when it allows him/her to avoid an unpleasant situation [43]. This theory can explain the simple fact that talking about vocal tics can cause an important increase of these manifestations. These hypotheses are partly based on observations that tics fluctuate in time, and today's research shows that cognitive and meta-cognitive factors may be involved [44].

In light of previous statements, a sound model of tic onset requires linking the role of many interrelated causes. An interactive and multidimensional model appears to be more plausible than a model based on a unidimensional or single linear causality [45,46].

Evaluation of GTS

A standardized checklist helps to create an individual profile that operationally defines the tic manifestations, while illustrating on the one hand the situations with more or less high probability of tic onset appearance, and on the other hand the behavioral functions of the tic. With a functional analysis examining behavior before and after tic onset, it is possible to identify the variables that maintain the tic. This structured evaluation facilitates the development of personalized intervention strategies to meet individual needs [47]. A functional analysis helps to distinguish tics from other repetitive behaviors such as compulsions, stereotypes or a habit disorder. Nonetheless, prior to intervention, it is recommended to perform a neurological, as well as a psychological, evaluation of the comorbidity.

■ Neuropsychological evaluation

Currently, a characteristic neuropsychological profile for a child with GTS is nonexistent, although certain abnormalities appear more commonly than in other clinical groups. The neuropsychological evaluation allows us to go beyond typical symptoms in order to broaden our understanding of GTS. It should be performed to eliminate other neurological syndromes. Earlier studies indicate little or no difficulties on global performances [48]. More specific investigations have underlined the presence of learning difficulties [49,50] and deficits in verbal fluency [50,51], visuospatial and visuomotor skills [49,52], and nonverbal memory [53]. Fine dexterity problems have also been noticed on the Purdue Pegboard among children [54], preadolescents [55] and adults [37]. Motor dexterity is a predictor of tics worsening in adolescence [54] and fine dexterity is important to evaluate because this motor component can be added as part of CBT according to O'Connor's model [35] described in the next section. A recent study further showed that steadiness and visuomotor integration of fine motor skills were altered in adult GTS, while precision and speed of movements were intact [56]. On the whole, targeted neuro-motor evaluations are likely to detect subtle cerebral dysfunctions, which would mainly relate executive and motor functions among children with GTS.

■ Preliminary evaluation & diagnosis of tics

The preliminary interview evaluates patients according to the DSM-IV-TR criteria of GTS [57,58]. Those who have been diagnosed with chronic tics must show motor or vocal tics occurring daily for at least 1 year. These tics are largely present around the upper facial region, mainly for eye tics, eye movement tics and eyelid/eyebrow movement tics [59] and represent a core feature of GTS. The preliminary interview assesses the presence of problems associated with addiction, infantile psychosis, mood disorders, anxiety disorders and other disorders diagnosed early in childhood. Certain elements in pervasive developmental disorders can also be confused with GTS such as stereotypical and ritualized behaviors. Intellectual disability and mental retardation among children also needs to be considered. It is also necessary to exclude the presence of recognized neurological problems (i.e., dyskinesia, hemifacial spasms, cerebral sclerosis, Huntington's chorea, stereotypical movements and Wilson's disease).

■ Structured evaluation of tics

The structured evaluation is essentially based on the developmental history, which will depict a detailed portrait of past and present tics, lifestyle habits and dysfunctional situations on a daily basis. The first diagnosis instrument was

the Tourette Syndrome Global Scale (TSGS) [60]. This instrument has several subscales. The first one assesses the type of tic (either vocal or motor), while the second one evaluates the complexity of the tic (simple or complex). A third subscale evaluates global behavioral problems, problems related to school, as well as behavioral disorders.

The most commonly used clinical evaluation for an accurate clinical picture relies on the use of the Yale Global Tic Severity Scale (YGTSS) [57]. The YGTSS, partially derived from TSGS, is a scale completed by the clinician to assess the symptom severity of the tic according to frequency, duration, intensity and complexity. These subscales are assessed using a 1–5 scale and are calculated separately for motor and vocal tics. They sum to form a global scale from 0 (no tics) to 50 (extremely severe). The YGTSS has demonstrated a good internal consistency and inter-rater reliability, as well as a good internal and external validity [57]. The convergent validity of the motor and vocal subscales has also shown significant correlations with the TSGS [61]. However, the YGTSS is not very sensitive to clinical change due to its categorical scoring system. The multidimensional TSGS is preferred in research.

■ Evaluation of associated factors

In addition to the standardized clinical evaluations, it is important to meet close relatives to facilitate the follow-up in different contexts, and then help build an efficient strategy. Associated symptoms such as hyperactivity profile can currently be assessed by the Connors' questionnaire, which is completed with the two parents and a teacher [62], anxiety and depression are assessed with the Beck Depression Inventory directly with the patient [63], the Life Event Survey [64], the Self Esteem Inventory [65], the symptoms of OCD for children [66] and finally a grid evaluating favorable contexts for the initiation of tics [67].

Intervention for treating chronic tics

The type of treatment initiated among GTS individuals is closely linked to the clinical profile and to the presence of associated disorders. The most disabling symptoms impacting on quality of life are prioritized for the treatment [11,15]. As discussed earlier, a series of brain dysfunctions could lead to an onset of tics and thus disrupt cognitive and motor functions. Tic treatment, in order to work in many cases requires many modalities of intervention such as pharmacological intervention, as well as different types of cognitive behavioral interventions. In this section, we present various components of the different interventions currently being developed in clinical research.

■ Pharmacological treatments

The majority of prescription drugs, as much among adults as among children with GTS, show a variable response, sometimes even in the same individual. No medication can lead to the complete remission of this syndrome and the dosage is usually graduated according to the presence of the dominant tic or behavioral symptoms. Owing to the clinical consensus that tics are a problem of the dopaminergic system, dopamine antagonistic neuroleptics are regularly the main treatment. Therefore, many researchers have observed that pharmacological agents that trigger an increase (agonist) in dopaminergic functions will exacerbate tics [68–70], whereas those that cause a decrease (antagonist) in the dopaminergic action tend to reduce the tic frequency [71,72]. Haloperidol (neuroleptic) and clonidine (antihypertensive) are currently the favored medication in the USA for the management of tics [73,74]. Among children and teenagers, controlled trials have shown that the frequency of tics decreases by 50% after the use of haloperidol or pimozide [75]. However, typical antipsychotics such as Haldol® (Johnson and Johnson Corp., NJ, USA) may cause extrapyramidal signs, characterized by involuntary movements, impatience and a need to constantly move, and significant trembling, among other symptoms. Atypical drug therapy or drug combinations are reserved for more complex cases as well as in the presence of associated disorders. However, side effects also occur in approximately 80% of individuals, and only 20–30% of patients afflicted with GTS continue pharmacological treatment for an extended period [76]. The effectiveness of risperidone (atypical neuroleptic) has progressively been proven to reduce tics, despite the possibility of significant long-term side effects, such as an increased risk of hyperglycemia and diabetes [77]. Other pharmacological agents (antidepressants or other neuroleptics) can provide positive results in reducing tics, but these results are often inconsistent and generally come from unique cases in nonrandomized trials [75].

In addition, the consumption of psychostimulants (e.g., methylphenidate) is not recommended given the increase in tics in children

with concomitant ADHD. However, the majority of recent studies show that the psychostimulants decrease ADHD symptoms without involving much of an increase of tics in the long term [78]. Furthermore, other studies have shown that the tic increase caused by psychostimulants is no longer visible after approximately 18 weeks of treatment, allowing the restriction on the use of psychostimulants among children with GTS and ADHD to be removed [79]. However, it is the caregiver's responsibility to inform the family of the possible secondary effects of psychostimulants.

■ Psychosocial interventions for tics

Pharmacological treatment is currently being administered to the most symptomatic children and remains, to this day, the first line of treatment despite the notable secondary effects [74]. However, CBT represents a useful complement to the medication and current guidelines suggest that CBT should be offered as first-line treatment to suitable patients, where such intervention is available [80].

Psychological treatments, unlike pharmacotherapy, also increase self-control and self-esteem. These treatments follow the lines of sustainable change when relapse prevention strategies are rigorously applied. Therefore, combining pharmacotherapy with CBT is probably the most effective treatment for tics [81].

Beneficial adjuncts for existing treatments are also applied, such as relaxation, hypnosis, biofeedback, negative reinforcement, response prevention and massaging of twitching muscles [82]. The treatment application can be adapted to the children's cognitive developmental level [83]. Therefore, little motivation, lacking of introspection and incomprehension of certain abstract notions must be adapted in order for the intervention to stay effective [41,84]. The theoretical concepts need to be concretely explained to allow the active involvement of the child in the therapeutic process, such as direct role playing and other activities. Treatment and therapeutic activities must not appear to the child as a task or a punishment for his/her behavior, but rather as a way to develop himself/herself and to feel better, and enhance his/her quality of life [85]. Generally speaking, psychotherapy, even if unstructured, can prove to be an appropriate solution to the syndrome's impacts, addressing low self-esteem, lack of social skills or incomprehension toward his/her symptoms [86].

■ Positive reinforcement approach

In order to reduce tics, the behavioral approach advocates positive feedback [87]. A positive reinforcement program is also suggested in conjunction with strategies previously acquired to control tics. Positive reinforcement alone, presenting itself as, for example, encouragements and praise, cannot eliminate tics because a swift return to the initial condition is generally observed. Nevertheless, it can be advantageously coupled with any intervention program.

Muscle relaxation also leads to sensory feedback, helping a global tension decrease and allowing a gain of sensory awareness. By proceeding with Jacobson's technique [88], the patient performs a series of exercises where his/her muscles from every part of the body alternate between tension and release. Additional exercises of abdominal breathing or visual imagery are sometimes included, especially for children [89]. The tension regulation and muscle stress tend to reduce tics for brief periods of time. Muscle relaxation is thus used to stabilize the effects of other interventions due to the difficulty in applying it in a generalized manner in everyday situations.

■ Cognitive behavioral interventions for tics

The main goal of CBT consists of modifying cognitive and behavioral activities in order for the individual to reduce the frequency and intensity of dysfunctional responses. Therefore, the goal is to support the modification of behaviors by a process of cognitive re-education and by integrating many cognitive and behavioral strategies. Habit reversal (HR) is one such CBT approach and is presented here because one of the steps requires an awareness of the cognitive, physiological and sensory process [82,89–91]. This HR model is essentially based on the learning theory and supported by the principle that the tic is a normal but amplified reaction, reinforced by operant conditioning. HR has thus been considered as one of the first effective CBTs that led to a decrease in tics [46,82,92]. The method includes five steps aiming at teaching self-control to the patient **(Figure 1)**. The exercises must be performed regularly and constantly, in a progressive manner, under the supervision of a therapist. The goal of the first step is to gain awareness of the pattern of tics. This is a crucial component in the decrease of tics by self-management. The next most important element of HR is based on the principle that the execution of a competing response antagonistic to the tic will eliminate the tic itself or decrease

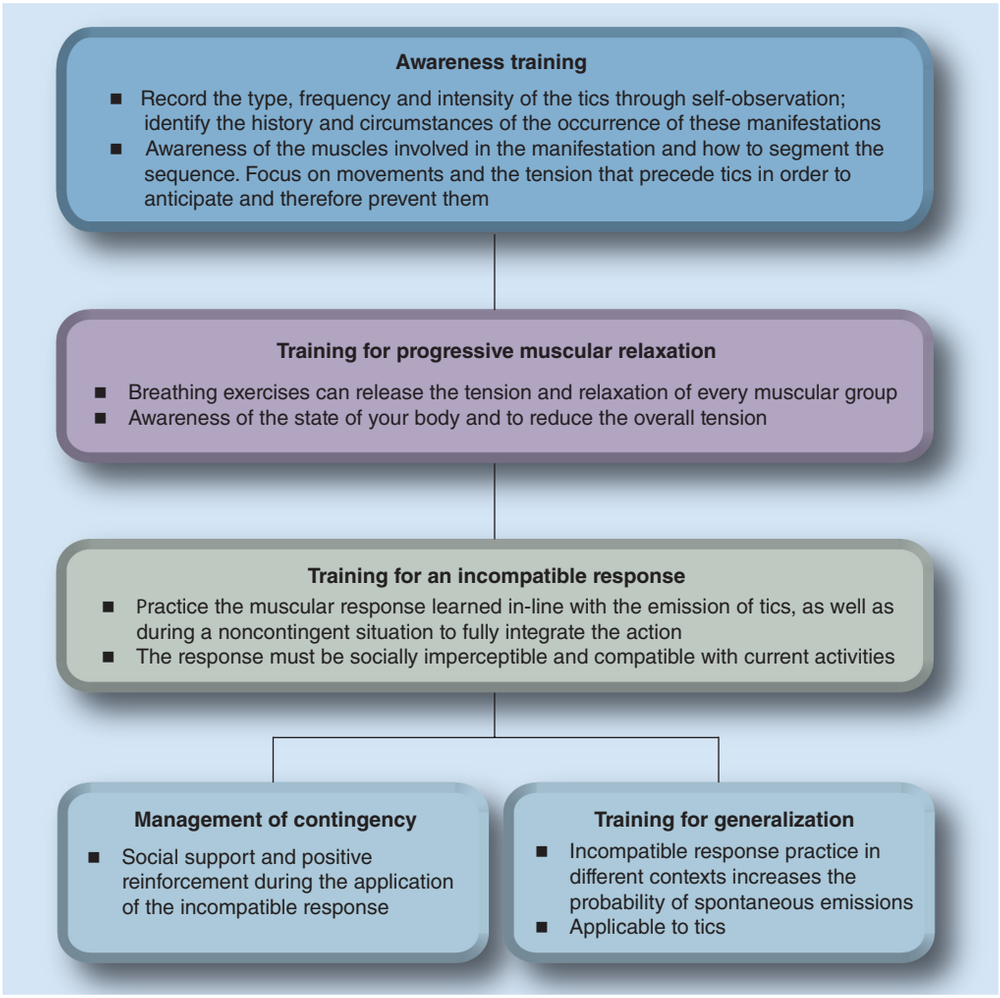

Figure 1. Azrin and Nunn's stage model for habit reversal.
Information taken from [42].

its intensity, because the environmental contingencies are transformed. Since the antagonist muscles are contracted, the tic onset is inhibited. For instance, resting the hand on an armrest or a table and pressing it downwards will prevent the jerking tic of the arm, and blinking in a slow and gentle manner can prevent eye blink. Sometimes, the response is more complex than the mere contraction of another group of muscles. An example would be to breathe deeply in order to prevent the occurrence of a vocal tic.

■ Cognitive, behavioral & psychophysiological interventions

Other intervention models focus on physiological factors underlying GTS manifestations. In these models, tics are considered to be a cluster of behavioral responses to increase muscular tension and sensorimotor activation [35,67,93]. The goal of Verdellen *et al.*'s model is to prevent tics by helping the patient to become aware of sensory warning signals [94]. The individual, therefore, identifies the precursor stimulus in order to later learn an alternate response to resist tics and become conscious of the premonitory urge or sensation; for instance, tolerating the urge longer or executing another action soliciting involved muscles (e.g., relaxation exercises). Consequently, the premonitory sensory urge decreases, and so does the tension that it generates. However, such a sensory desensitization procedure seems to provide only short term and nongeneralizable results for managing tics [95].

The cognitive psychophysiological model

The cognitive psychophysiological model of tic behavior builds on previous behavioral approaches; but rather than addressing the tic

in isolation, it aims to change the background behavioral context against which the tic occurs. Previous behavioral research has clearly established the tic as a behavior over which the person can exercise semi-voluntary control. People can suppress tics, withhold tics and change location of the tic. This research has also shown that tics do not occur in a vacuum. High-risk–low-risk profiles relate to activities, reactions and personal evaluations occurring at the moment of tic onset. In particular, activities where the person feels judged, constrained, frustrated or dissatisfied are more likely to be more high risk [45]. Anecdotally, it is known that when attention is engaged and the person is absorbed in an activity, tics reduce. It is clear that cognitive and meta-cognitive factors (anticipating tic interference in an activity) tie in with basic physiological processes (e.g., muscle contraction) to enhance tic onset [44].

Such cognitive physiological loops have been ignored in neurological models but can be well integrated into motor psychophysiological accounts where feed-forward intentions can influence the nature and flow of movement.

All these factors suggest that tics, although the defining symptom in GTS, require a background of other behavioral processes in order to occur. Even the updated version of HR, namely comprehensive behavioral intervention for tics, recognizes the benefit of addressing competing behaviors rather than just antagonist muscle responses.

A key background characteristic of tics is heightened sensorimotor activation, present in GTS in a number of measures: planning action, reaction time, lower sensory threshold and higher cortical arousal. This high level of sensorimotor activation is sometimes mistaken for hyperactivity, but (as with other comorbidities in GTS) it is rather a feature of GTS that we term overactivity to distinguish it from hyperactivity. This overactive style of planning is present in everyday life. Interestingly, it is identified predominantly alongside perfectionism, although there are impulsive elements. This perfectionism often creates an inhibition effect on planning in GTS, and can lead to a conflict with impulsive actions. The person wishes to act quickly but the action is inhibited or delayed by perfectionist beliefs. This conflict complicates the action and is coupled with a sensorimotor requirement for actions to 'feel' just right. Often there is a consequent overpreparation and reliance on proprioceptive feedback to signal completion. This conflict explains the feelings of frustration and impatience often present at tic onset. Revolving this perfectionist–impulsive conflict forms a corner store in the cognitive psychophysiological approach.

O'Connor's model [35] adapts certain elements according to symptoms identified by contemporary research and observations specific to patients with GTS, especially when it comes to planning and organizing actions. These investigations have led to clinical, psychometric and physiological results that are integrated in a cognitive, behavioral and physiological treatment. An important part of O'Connor's model is the attempt to combine behavioral principles with knowledge of behavioral processes affected in GTS. In essence, the model holds that tics are produced by heightened sensorimotor activations **(Figure 2)**. This activation is complex and among its manifestations are chronic muscle tensions. The specific tension appears to be produced by the interaction of inhibition and impulsivity. The consequences are that individuals who suffer from tics are caught in a frustrated action cycle where they are overpreparing for action and overactive at the same time. These two components have recently been operationalized in development and validation of a STOP questionnaire whose subscales discriminate tic and habit disorder from other obsessive complusive spectrum disorders [61]. Interestingly, although these subscales relate moderately to impulsivity, unlike ADHD they relate more strongly to perfectionism and being 'just right'. The theory suggests that addressing this conflict and tension and overcoming frustration through a cognitive and metacognitive strategy will better prevent tic occurrence than simply inhibiting or otherwise antagonizing the tic. The cognitive psychophysiological model helps us understand why tics can be labile and change from week to week, since they are just the symptom of an underlying overactivation process. The model also helps in understanding the variable associations of the GTS with other disorders, since many of the disorders (symptoms resembling ADHD, rage syndrome and OCD) are part of the problem, not separate disorders. Overactivity, sensorial touching and emotional tics can be mistaken for ADHD, OCD and rage, but are in fact part of the heightened sensorimotor activation found in the GTS. As mentioned previously, the STOP questionnaire aids differential diagnosis.

O'Connor's model considers the release of tension as part of a general sensorimotor regulation system **(Figure 2)**. On the one hand, it suggests that the evaluation of tics must focus further on

situational triggers beyond external cues of a social or environmental character, which are more difficult to generalize in light of their idiosyncratic nature. On the other hand, the individuals with a tic disorder or GTS have a particular style of action characterized by overpreparation and overactivity that tends to increase muscular activation and tension, in part because of individual perfectionist expectations. The analysis of this overactivity, and of what it represents for the individual, then allows the classification of situations into high or low risk of tic onset. For example, driving may be relaxing and constitutes a break during the day, but it may also be considered as a stressing action if the individual expects and plans to do more things during the day. The intervention program aims to prevent the emergence of the tic by global behavioral restructuring and by re-education linked to the planning of movements and actions.

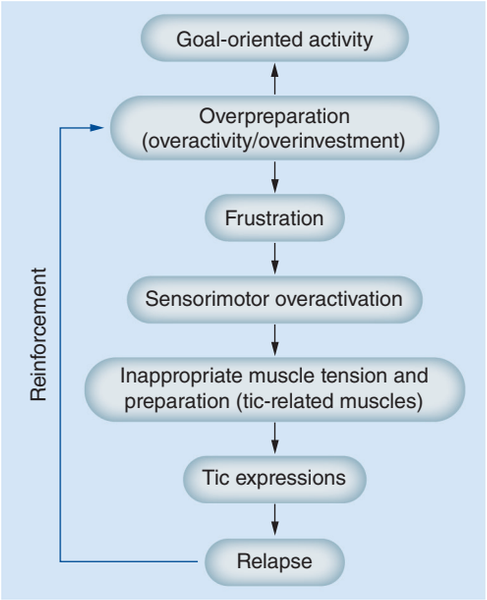

Figure 2. Cognitive behavioral and psychophysiological steps of O'Connor's model (2002).
Information taken from [35].

Effectiveness of cognitive behavioral interventions

■ Studies on HR

Studies on HR show a decrease in tic frequency from 75 to 100%, with maintenance of progress for the following 2 years [96,97]. However, these results were collected during experiments with small numbers of participants from various populations affected with chronic tics, GTS or habit disorders. Recently, this type of behavioral therapy was evaluated in a multisite randomized controlled trial that followed 126 children between 9 and 17 years of age who are afflicted with GTS or chronic tics [81]. In this study, all children were randomly assigned to eight sessions of behavioral therapy during 10 weeks or to support and education therapy sessions. The sessions of behavioral treatment helped to significantly decrease the tic symptoms in comparison with the support therapy (53 vs 19%, respectively) with lasting effects for 6 months in 87% of cases.

The HR model is the first treatment to be applied in a school context, achieving a significant decrease in tic symptoms [98]. Teachers and students consider that the intervention is effective in reducing tics and impulsivity. This technique tends to increase self-esteem by giving a certain empowerment over their behavior. In order to determine the most efficient components of this model, some researchers have assessed abridged versions of HR [46,85,92,99]. The results show that awareness and training of an incompatible answer are the most significant elements for the effectiveness of a HR treatment from childhood to adulthood. However, a major problem with behavioral techniques, even when tailored to GTS populations, is that they are adapted from general behavioral principles, but do not address processes specific to GTS.

■ CBT & psychophysiology for treating chronic tics

O'Connor's results highlight the complex interactions between cognitive, behavioral and psychophysiological factors in a model where tics are a function of sensorimotor self-regulation [61,67]. In a study evaluating the treatment effect, 65% of participants reported having a 75–100% degree of control over tics after the intervention. Nonetheless, 52% of the participants maintained these improvements after 2 years [67]. Despite the innovation and evolutionary character of this model, more studies are necessary in order to validate the foundation and the efficiency of this intervention program to better assist clinicians. A randomized trial established the validity of this treatment among adults, mainly for chronic tics [35]. In this study, tics were evaluated with videos, notebooks and by relatives in order to get a triangulation between sources **(Figure 3)**. A more recent open trial of 120 people diagnosed with either tics or habit disorders reported significant reductions in tics. Both cognitive behavioral and symptom

Date	Hour	Frequency	Intensity (1–5)	Control (0–100%)	Resistance (0–100%)	Situation activity

Figure 3. Examples of situational and contextual notebooks for the expression of tics. This table is an example of that used in [35], collating and evalutating the changes in tic expression.

measures showed dramatic reductions [O'Connor KP *et al.* Further validation of a cognitive behavioral psychophysiological intervention for tic and habit disorders (2012), Manuscript in preparation]. Underlining the role of both cognitive and psychophysiological factors is emerging interest in the plasticity of the brain in GTS. Cognitive behavioral retraining in motor planning can produce changes in cortical functioning. Thus, before treatment, GTS patients had reduced electrophysiological response in comparison with the control group during a motor inhibition task. Following CBT administration, this response was normalized concomitantly with the decrease in tic frequency [100].

Conclusion & future perspective

Improved treatment for managing symptoms of GTS lies in a combination of multidisciplinary interventions, in particular pharmacotherapy supported by a treatment such as CBT [15,101]. Effective and individualized therapeutic action should not only include the modification of motor symptoms, but also cognitive strategies to deal with tics and metacognitive beliefs (e.g., about the inevitability of tic onset) [44]. It is necessary to broaden our conception of GTS in order to see it not only as a neurologic, but also as a psychophysiological syndrome. This approach nonetheless needs to combine restructuring of both cognitive and behavioral aspects, while taking into account physiological aspects that can also exacerbate the behavioral reactions. This psychotherapeutic approach has recently shown promising results [103].

There is good reason to develop CBT for children afflicted with GTS. First, symptom severity is considered to be important between the age of 10 and 12 years. Second, medication does not offer persistent effects to everyone and its utilization can cause significant side effects. Finally, the elevated presence of associated disorders can entail a certain resistance to treatment for behavioral and physiological reasons related to the increased variety of symptoms [41]. CBT promises to offer an alternative to pharmacotherapy that allows working on the most disruptive symptoms individually. HR demonstrates convincing results in different studies on children with GTS or a tic disorder [98,102]. O'Connor's model, taking into account cognitive, behavioral and psychological factors, was recently adopted for teenagers and for children manifesting explosive outbursts [84,104]. The results are interesting, but more studies are necessary in order to validate the effects of treatment on children.

In conclusion, two considerations appear to be fundamental for the development of specialized interventions for GTS in the near future. First, integrating psychophysiological technology as an instrument of treatment: these new possibilities can support cognitive and behavioral reconstruction through learning self-controlled psychophysiological strategies. Second, the dissemination of study results on alternative interventions or other front-line treatments must occur. Finally, treatments for GTS symptoms, empirically acknowledged to be effective, should be presented to the public and be more accessible.

Acknowledgements

The authors would like to thank C Litwin and B Zhang for their helpful corrections to an earlier draft of this article.

Financial & competing interests disclosure

The authors would like to acknowledge funding support from the Canadian Institute of Health Research, grant no.: MOP57936 and MOP93556, and the Fonds de la Recherche en Santé du Quebec, grant no.: 20573. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

No writing assistance was utilized in the production of this manuscript.

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