



## Research report

# Illusion of agency in patients with Gilles de la Tourette Syndrome



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## ABSTRACT

The sense of agency refers to the conscious experience of authorship and control over actions.

The voluntary or involuntary nature of tics, which are the hallmark of Gilles de la Tourette Syndrome (GTS), is unclear. Here, we studied metacognitive processing of agency in an explicit agency task on non-medicated and medicated GTS patients compared to matched controls. In this task, the participants made judgements of control and performance after completion of a computerized game where they had to catch targets with a cursor by moving the computer mouse. The task included several conditions, where the objective control over the cursor could be normal, disrupted or artificially enhanced. We show that GTS patients, independently of medication status, based their judgments of agency predominantly on the matching between their intention and the outcome, i.e., had an illusion of agency in the task condition where their performance was artificially enhanced. Nevertheless, they recognized not to be fully in control in conditions of disrupted control. The propensity to illusions of agency was negatively correlated with global disease severity.

Our findings suggest alterations of metacognition of agency in GTS patients. This illusion of agency could reflect a compensatory mechanism related to tic control, but is more likely to be related to deviant brain maturation in GTS.

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## 1. Introduction

Volition and consciousness of intentions are fundamental features of human motion. The sense of authorship and control over self-produced actions is referred to as the sense of agency (Gallagher, 2000; Pacherie, 2008), which involves two main processes: a low-order, unconscious, implicit, sensorimotor “feeling of agency”; and a high-order, conscious, explicit, metacognitive “judgment of agency” (Synofzik, Vosgerau, & Newen, 2008; Synofzik, Vosgerau, & Voss, 2013).

Altered sense of agency, either feelings of control over externally-generated actions (“illusions of control”), or loss of control over self-generated actions (“delusions of control”) have been described in some psychiatric and neurological disorders (Frith, Blakemore, & Wolpert, 2000; Moore & Fletcher, 2012; Sato & Yasuda, 2005). For instance, disorders characterized by abnormality of motor control such as alien hand syndrome (Pacherie, Green, & Bayne, 2006) or functional movement disorders (Edwards et al., 2011; Voon et al., 2010) have been associated with abnormal sense of agency.

Gilles de la Tourette Syndrome (GTS) is a childhood-onset neurodevelopmental disorder characterised by the presence and persistence of hyperkinetic movements and abnormal vocalisations, called motor and vocal tics (Leckman, 2002). The voluntary or involuntary nature of tics is unclear (Leckman, Peterson, King, Scahill, & Cohen, 2001). Tics are generated in the same neural pathways as voluntary movements (Hallett, 2001) and they can be voluntarily suppressed. However, tics are often experienced as escaping voluntary control. Tics are also often preceded by ‘urges’ that can be described as intentions to move. The semi-voluntary nature of tics may be related to an abnormal conscious experience of action (Cavanna & Nani, 2013) and the ability to suppress tics related to the conscious experience of the intention to move (Ganos et al., 2015).

The feeling of agency relies on the comparator model of action control. An action is felt as self-generated if the efference copy of a motor plan generated by a forward model matches the actual sensory effects of the action (Desmurget & Grafton, 2000; Kawato, 1999; Wolpert & Ghahramani, 2000).

The judgment of agency is a metacognitive retrospective inference (Wegner & Wheatley, 1999) formed by synthesizing information from the feeling of agency and other cues such as perceived performance, matching between intentions and outcomes (Weiss, Tsakiris, Haggard, & Schütz-Bosbach, 2014), and personal beliefs (Bayne & Pacherie, 2007; Desantis, Roussel, & Waszak, 2011).

The sense of agency can be studied experimentally by means of implicit or explicit measures. Implicit agency studies use perceptual differences between self- and externally-generated stimuli, like the intentional binding effect (Haggard, Clark, & Kalogeras, 2002) or sensory attenuation (Hughes, Desantis, & Waszak, 2013). Explicit agency studies use tasks in which the visual feedback of a self-generated action is spatially (Daprati et al., 1997) or temporally (Farrer, Bouchereau, Jeannerod, & Franck, 2008) distorted, and ask participants to make metacognitive judgments about their degree of authorship and control over the action.

In GTS, implicit agency studies yielded conflicting results. Indeed, one study showed that GTS patients had a delayed experience of volition compared to healthy controls (Moretto, Schwingsenschuh, Katschnig, Bhatia, & Haggard, 2011). In a second study, these findings were not replicated but the authors found a correlation between an early experience of volition and the ability to suppress tics (Ganos et al., 2015). Explicit agency has not been studied to date in GTS.

Here, using an explicit agency task, which tests subjects’ ability to recognize incongruences between their actions and a visual feedback and to make appropriate judgments of agency, we addressed the question of the sense of agency in GTS patients. The task used has been shown to be sensitive to metacognitive judgments of agency in healthy subjects (Metcalf, Eich, & Castel, 2010; Metcalf, Eich, & Miele, 2013; Metcalf & Greene, 2007), and to alteration of agency in pathological conditions such as schizophrenia (Metcalf, Van Snellenberg, DeRosse, Balsam, & Malhotra, 2012) or autistic spectrum disorders (Zalla, Miele, Leboyer, & Metcalf, 2015).

We hypothesized that patients with GTS would present alteration in their metacognition of agency compared to healthy controls, particularly in matching between their intentions and the outcomes. To control for the effect of antipsychotic treatments, we included both medicated and unmedicated GTS patients in the study.

## 2. Materials and methods

### 2.1. Patients

The local ethics committee approved the study and every participant gave informed written consent for participation.

Patients were recruited from the GTS Reference Centre at Salpêtrière Hospital in Paris, and examined by a multidisciplinary team experienced in GTS.

Inclusion criteria for patients were: i) age >18 years ii) having a confirmed diagnosis of GTS according to the Diagnostic and Statistical Manual of Mental Disorders-5 criteria. Exclusion criteria were i) co-occurrence of Axis I psychiatric disorders [established by the Mini International Neuropsychiatry Inventory (Sheehan et al. 1998)]; autistic spectrum disorder, substance abuse aside from nicotine, current major depressive episode, current or past diagnosis of psychotic disorder ii) any neurologic disorder other than tics. We recruited both unmedicated and antipsychotic-treated patients. Medicated patients had to be on stable antipsychotic treatment for at least four weeks. The severity of tics was assessed by the Yale Global Tic Severity Scale (YGTSS) (Leckman et al. 1989).

Controls were recruited by the Resource for Biomedical Research Volunteers and by university-based advertisements. Inclusion criterion was an age over 18 years. Exclusion criteria were the same as for GTS patients, plus i) a personal history of tics ii) any concomitant treatment except contraceptive pill for women.

### 2.2. Agency task

The task has been described in detail elsewhere (Metcalf et al., 2010; Metcalf & Greene, 2007). Briefly, during game

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