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Executing motor tics in response to experimentally generated urges reduces subjective inconvenience but potentiates their physiological impact.

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Table of contents

“*The more a tic is repeated, the more inveterate it becomes, and the greater the likelihood of its becoming generalised.”*

Édouard Brissaud, 1902

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ABSTRACT

OCD patients attempt to alleviate uncertainty (e.g. is the door closed?) by perseveration, such as extensive checking rituals, with counterproductive, paradoxical results: feelings of uncertainty usually increase. In a similar vein, Tourette Syndrome patients respond to premonitory urges with tics, and claim that these urges are relieved by executing the tic. Analogue to findings in OCD, it was hypothesized whether similar paradoxical effects occur in TS. In healthy participants, it was investigated whether deliberately executing a motor tic in response to experimentally induced sensations in the same region sensitizes to these sensations, both subjectively as well as physiologically. Against hypothesis, findings suggest that tics are rewarded as they subjectively reduce the subjective annoyance of future urges as well as the tendency to respond to them. However, physiological measures indicate that executing tics ultimately results in increased physiological activity in the tic region compared to a control condition, possibly representing a sensitisation to the stimuli, or a failure to habituate to future urges. Implications for the theoretical understanding of tic behaviour and the efficacy of treatments such as exposure and response prevention are discussed.

Introduction

Gilles de la Tourette Syndrome, or Tourette's Syndrome (TS) is one of the most widely known and most severe tic disorders. Having a prevalence of 1% (Robertson, 2008), TS patients execute *tics*: sudden, repetitive abnormal movements or vocalisations. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria, TS is diagnosed when multiple motor tics and at least one vocal tic are present for at least a year, with an onset before the age of 18 years (APA, 2000). Motor tics often involve musculature in the face and the neck, such as eye-blinking or head-shaking, and vocal tics can vary from throat-clearing and coughing to more complex variants like coprolalia (uttering obscene or offensive words or phrases), a symptom occurring in less than one-third of TS patients (Robertson, 1994). Throughout history, a large number of approaches have been developed to alleviate TS symptoms, often more inventive than effective, such as soaking patients in caustic solutions, applying static electricity, prolonged isolation, sea voyages, cocaine usage, hypnotic suggestion, electroconvulsive treatment, and transcendental meditation (see H.C. Parraga, Harris, K.L. Parraga, Balen, & Cruz, 2010, for a historical review). Currently, pharmacological tic management and cognitive-behavioural treatment may alleviate symptoms, but curing TS is not possible (Robertson, 2000; Parraga et al., 2010).

Tourette's Syndrome is in several ways related to Obsessive Compulsive Disorder (OCD), a condition characterised by obsessions (recurrent intrusive thoughts) and compulsions (repetitive behaviours performed according to a certain set of rules; APA, 2000). This relation is discussed in detail by Robertson (2000). There is a strong epidemiological relation: approximately 40 percent of TS patients also show (subsyndromal) OCD symptoms and behaviour (Robertson, Trimble, & Lees, 1988; van de Wetering, Cohen, Minderaa, Roos, & van Woerkom, 1988; Caine, McBride, Chiverton, Bamford, Rediess, & Shiao, 1988; Cath et al., 2001) while OCD occurs only in less than 3% of the general population (Dinan, 1995). Additionally, sensory and mental phenomena associated with tics in TS and compulsive behaviour in OCD show considerable phenomenological overlap, such as a 'just-right' feeling resulting from both compulsions and tics (Leckman, Walker, Goodman, Pauls, & Cohen, 1994; Turpin, 1983). Thirdly, Robertson (2000) argues that at least some forms of obsessive compulsive behaviours or symptoms are genetically related to TS (Pauls and Leckman, 1986; Pauls et al., 1986, 1991, Eapen, Pauls, & Robertson, 1993; in: Robertson, 2005). Finally, both OCD and TS are effectively treated with using exposure and response prevention techniques (Cox, Swinson, Morrison, & Lee, 1993; van Balkom, van Oppen, Vermeulen, van Dyck, Nauta, & Vorst, 1994; Kobak, Greist, Jefferson, Katzelnick, & Henry, 1998; Abramowitz, 1998; Franklin, Abramowitz, Kozak, Levitt, & Foa, 2000; Verdellen, Keijsers, Cath, & Hoogduin, 2004). This therapeutical overlap does of course not prove that both disorders share an underlying pathological mechanism, but it adds to the similarities between TS and OCD.

OCD patients respond to feelings of uncertainty by perseveration, such as extensive checking rituals (Tallis, 1995), which is shown to be counterproductive. In a series of experiments with healthy participants, checking whether a virtual gas stove was turned off resulted in a *less* detailed and vivid memory of this situation (Boschen & Vuksanovic, 2007; Coles, Radomsky & Hong, 2006; van den Hout & Kindt 2003a, 2003b, 2004). This paradoxical effect of checking behaviour persists when using real-life stimuli (Coles et. al. 2006; Radomsky, Gilchrist & Dussault, 2006), abstract stimuli (Dek, van den Hout, Giele, & Engelhard, 2010) and is present in OCD patients (Boschen & Vuksanovic, 2007). Somewhat similarly, Tourette patients respond to premonitory urges with tics. Premonitory urges are sensory sensations, or feelings of incompleteness, or of 'energy' (Leckman, Walker, & Cohen, 1993), that precede tics (see also Bliss, 1980, for a first-person description of these urges). Premonitory urges occur in a large majority of tic patients, for example, in 93% of patients in a systematic study (Leckman et al., 1993). Typically, TS tics are seen as output phenomena, and premonitory urges are considered to precede them. Patients however claim that premonitory urges are reduced or relieved by executing tics (Leckman et al. 1993; Bliss, 1980). In this way, tic behaviour might be reinforced. Over a century ago, Brissaud suggested that "*the more a tic is repeated, the more inveterate it becomes, and the greater the likelihood of its becoming generalised"* (Brissaud, 1902). Possibly, TS patients tic to seek relief from unpleasant sensations, but with paradoxical effects. The present experiment puts this hypothesis to the test.

In healthy participants, it is investigated whether deliberately executing a motor tic with the eye in response to experimentally induced sensations in the same region sensitizes to future urges, both subjectively as well as physiologically. To this end, participants receive, in phase A, a series of air puffs on the eye as a proxy for premonitory urges. EMG activity of the musculus orbicularis oculi is recorded, and subjective ratings are taken of puff annoyance, puff intensity, and blink urge. In phase B, the experimental group is instructed to briefly and firmly close or squeeze the eyelid each time an air puff is administered. In the control condition, participants are given no such instruction. Phase C is equivalent to phase A, constituting post measurements. It is expected that, from phase A to C, participants from the experimental condition will show an increase in subjective ratings of puff annoyance, puff intensity, and urge to blink, as well as an increase EMG activity in the musculus orbicularis oculi, compared to the control condition.

Method

Pilot study

To assess how hardware (custom built for this experiment) and software would be best set up, and to check whether varying air puff length results in differences in blink amplitude, a small (*n* = 5) pilot study was conducted. This pilot study is described in detail, in appendix A.

Main study: participants

Forty-seven healthy participants (mean age 22.4, *SD* = 2.3; 31 females) participated in exchange for remuneration or course credit. Current tics, a tic history or a family history of tics served as exclusion criteria. To this experiment, 15 participants who wore or who had worn contact lenses for a substantial period of time (i.e. several months or more, at any moment in their lives) were admitted. During the study however, it became apparent that these participants showed little to no visible response to the air puffs. They were noticeable to these participants, and did occasionally cause some minor sensations, but probably because repeatedly placing a contact lens in the eye desensitisizes this area, the average amplitude of the blink reflex in this group (29,0 ηV) was almost half that of the average amplitude of those who did not wear lenses (54,1 ηV). An independent sample *t*-test indicated that this difference was significant: $t(45) = 1.70$, $p < .05$, one-tailed, and these 15 participants were excluded from further analysis, so that 32 participants remained.

Figure 1: *The hard-plastic tip at the end of the air puff apparatus.*

Materials

The experimental setup consisted of several components listed here briefly: a] the apparatus delivering software-controlled air puffs to the participants eye to elicit the blink response (also known as the Puff-O-Matic™), b] the hardware and software required to record the blink signal from the musculus orbicularis oculi, and to quantify it into useable data, c] the VAS-questions to assess subjective ratings, and d] several auxiliary peripheral devices primarily aimed at diverting participants attention away from his or her own blink responses to the air puffs. These components are now discussed in detail.

Air pressure was delivered by a modified Kooltronic V64 cooker hood air turbine. Its exhaust shaft was sealed off using a wooden plank, with the exception of a plastic tube leading to a valve that could open and close, transforming the constant air pressure into discrete air puffs. This valve, a Teflon high purity Valcor Scientific, type SV51C56T34-8, devised by Inacom Instruments, was software-controlled by the stimulus presentation package E-Prime 2.0®. From the valve, a tube with a diameter of 80mm transported the air puffs to a conical hard-plastic tip with a 1.5mm diameter opening directed at the participants eye using an adjustable microphone standard. Distance between the end of the tip and the eye was approximately 2cm. See Figure 1 and 2. Musculus orbicularis oculi activity was recorded following the guidelines for eye blink electromyography studies published by Blumenthal, Cuthbert, Filion, Hackley, Lipp, & van Boxtel (2005). Two 8mm electrodes were placed on the musculus orbicularis oculi; Lectron II conductivity gel transported the electric signals from the skin to the electrodes. Additionally, one 12mm grounding electrode was applied to the central forehead. The signals were recorded by a Coulbourne isolated bioamplifier type V75-04 with band pass filter (amplifier coupling: 1.0Hz; gain: 10k, high pass: 13Hz; low pass: 150Hz). Signals were analysed using Startle Analyser v10.20, which normalized the signals and calculated blink amplitudes. These were defined as the difference between the highest point reached in the 20-140ms time span in relation to a baseline voltage that was calculated by taking the average voltage in the -40ms / +10ms time span (with 0ms being stimulus onset). See Appendix B for a detailed explanation of the exact qualification and selection criteria for these blink responses.

Figure 2: *Participants placed their heads in a black metal headrest.*

Subjective ratings were acquired by four 0-100 VAS items. These items covered a broad array of the experiential spectrum: how annoying the puffs were perceived to be (an emotional judgement of the stimulus), how strong they were perceived to be (a perceptual judgment of the stimulus), and how the subjects judged their urge to blink following each puff (a judgement of their reaction). See Table 1 for details.

Lastly, peripheral devices included a headrest in which the head was fixated to prevent any movement from disturbing the EMG signals. See figure 2. Approximately 40 cm in front of the participants, a distraction picture was placed with neutral content (a picture of a densely furnitured kitchen). This picture is included in appendix C.

Table 1: *Vas items used in pre and post measurements.*

Question	0	100
How did you judge the air puffs?	Not unpleasant at all	Very unpleasant
How did you judge the air puffs?	Not annoying at all	Very annoying
How strong were the air puffs?	Unnoticeable	Very strong
How strong was the urge to blink?	No urge at all	A very strong urge

Preparation

Participants were informed about the general procedure of the experiment without giving away any information that might influence their behaviour in any way disruptive to the study's goals. To prevent participants from concentrating on their own blink reflex, which might increase the salience of the stimuli or perhaps increase/decrease blink behaviour, participants were told that during the experiment, about anything might happen, such as air puffs, smells, sounds, flashes of light, and that the experimenter was blind to condition. Sound clicks were included in this 'circus' of possible events as the valve producing the air puffs made a distinct clicking sound. After this instruction, participants signed an informed consent form. As pilot participants reported that the experimental setup as a whole, featuring the black metal headrest and the pointed tip aimed at the eye, caused minor anticipation anxiety, participants were familiarized with the experimental procedures to reduce any possible tension, which would probably alter EMG signals by causing an increase in skin conduction, to a minimum. To achieve this, the Puff-O-Matic was switched on (i.e. air puffs started to emerge out of the small tip visible in Figure 2) and participants were introduced to the apparatus in a careful, step-by-step manner. This was done by taking out the tip of its rest and letting participants hold it in their own hands first to reduce any anticipation anxiety to the lowest possible degree. Finally, the electrodes were attached and EMG data recording was checked for noise artefacts following Blumenthal et al. (2005) guidelines.

Procedure and assessments

Phase A: with the electrodes in place, participants were instructed to place their chin on the headrest and were asked to look at the distraction picture. The Puff-O-Matic was switched on and produced ten air puffs of 200ms in length. Interstimulus interval (ISI) was random between 3000 and 5500ms. The blink amplitude of the musculus orbicularis oculi was recorded, and following these first air puffs, participants completed the first set of VAS items (see Table 1). In phase B, participants received 30 air puffs with a 200ms pulse duration, again with ISI varying randomly between 3000 and 5500ms. The experimental group was given the crucial instruction to briefly (slightly less than a second, but not shorter) but firmly squeeze both eyes, as soon as they heard a clicking sound or felt an air puff (which co-occurred 100% of the time). The entire experimental phase lasted about 130 seconds. See figure 3 for an indication of the firmness of the blink.

Wrong Correct

Figure 3: On the right: t*he squeezing motion that was the experimental manipulation. The left picture shows a normal blink. The instruction continued until participants performed the correct movement a few times consecutively.*

The control group was not given any instruction at all, but in the time period in which the experimental group received their instructions (the beginning of phase B), a break of about 30s was taken to minimize between-group differences. The final phase C, post measurements, was identical to phase A: 10 air puffs with EMG recordings, followed by the same four VAS items. For this phase, the experimental group was told that squeezing the eyes firmly as a reaction to sounds or puffs was no longer required, and they were asked to only study the distraction picture, just as they did in the first phase.

Results

Data preparation

One participant gave the most extreme answer possible (0 or 100) on every item. Furthermore, in response to the air puffs, he showed no blink reaction at all, although he claimed never to have worn contact lenses. It was decided to remove all his data from the experiment.

Outliers.

Outliers ($-3.29 < z < 3.29$) were replaced by scores deviating 3.29 standard deviations from the mean. This happened on one occasion within the variable EMG ratio (discussed below).

Puff unpleasantness

To assess whether changes in subjective ratings of puff unpleasantness varied across conditions, a repeated-measures ANOVA was conducted with Condition (Controls, Experimental) and Time (Pre and Post). There was no main effect for Time: $F(1,29) = 0.03$, $p = .86$, $\eta_p^2 = .00$, nor for Condition: $F(1,29) = .40$, $p = .54$, $\eta_p^2 = .01$. Additionally, the Time x Condition interaction was not significant: $F(1,29) = .15$, $p = .70$, $\eta_p^2 = .00$. Figure 4 shows ratings of puff unpleasantness for both conditions; see Table 2 for means and standard deviations.

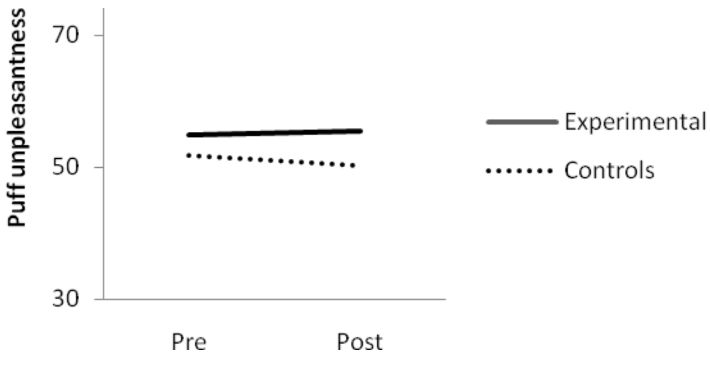

Figure 4: *Subjective ratings of puff unpleasantness on a 0-100 VAS scale.*

Puff intensity

A repeated-measures ANOVA was carried out to investigate reported puff intensity in both conditions. There was no main effect for Time $F(1,29) = 1.78$, $p = .19$, $\eta_p^2 = .06$, nor for Condition:

F(1,29) = 1.32, p = ., η_p^2 = .04. There was no significant Time x Condition interaction: F(1,29) = .03, p = .85, η_p^2 = .00. See Figure 6 for ratings on puff intensity, and Table 2 for means and standard deviations.

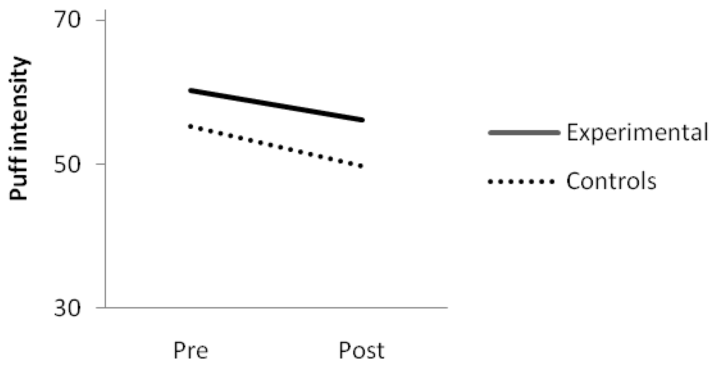

Figure 6: *Subjective ratings of puff intensity on a 0-100 VAS scale.*

Puff annoyance

A repeated-measures Time x Condition ANOVA showed that there was no main effect for Time: F(1,30) = 1.92, p = .18, η_p^2 = .06, nor for Condition: F(1,30) = 0.05, p = .94, η_p^2 = .00. The crucial Time x Condition interaction however was significant: F(1,30) = 4,96, $p < .05$, η_p^2 = .15; in the experimental group, puff annoyance decreased stronger over time compared to the control condition. See Figure 5 for a graphical depiction, see again Table 2 for means and standard deviations.

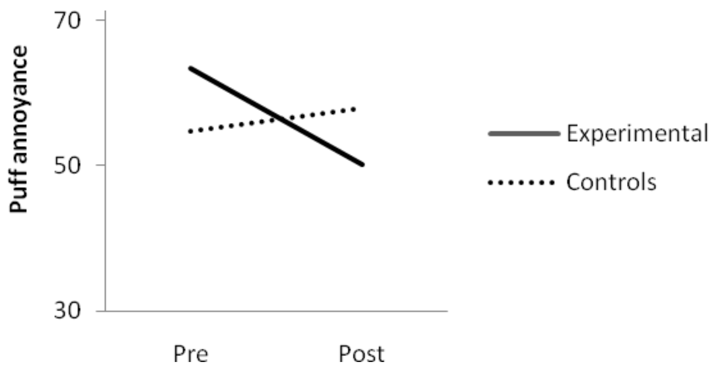

Figure 5: *Subjective ratings of puff annoyance on a 0-100 VAS scale.*

Blink urge

A somewhat similar pattern occurred for the blink urge in response to an air puff as measured with a 0-100 VAS scale. A repeated-measures ANOVA showed that there was a strong main effect for Time F(1,29) = 31.36, $p < .000$, η_p^2 = .52, but not for Condition: F(1,29) = 0.91, p = .35, η_p^2 = .03.

The decrease in blink urge was however stronger for the control group compared to the experimental group, indicated by a significant Time x Condition interaction effect: $F(1,29) = 4.43$, $p < .05$, $\eta_p^2 = .13$. This interaction is visible in Figure 7, means and standard deviations of all VAS ratings are presented in Table 2.

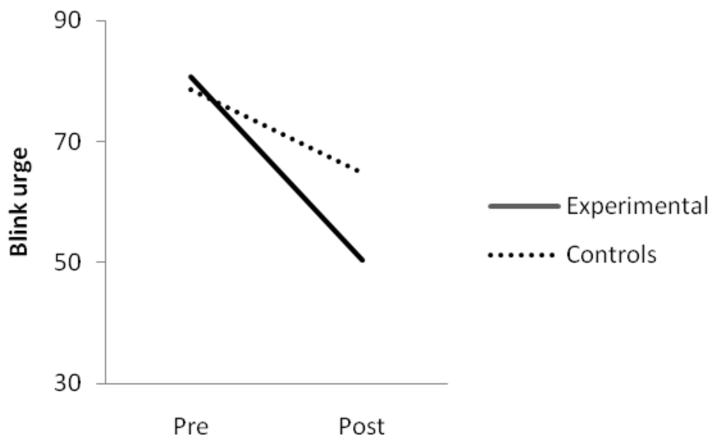

Figure 7: *Subjective ratings of blink urge on a 0-100 VAS scale.*

Electromyographic recordings of the blink reflex

Visual inspection of EMG data showed a large variance between participants in blink amplitude. Some participants had blink reflexes in the range of 100-200ηV, those of others varied between 10-35ηV. To prevent those of the first category from having a stronger weight on the results than those of the latter, pre-to-post change *ratios* were calculated for each participant, using the following formula:

$$\text{EMG ratio} = \frac{\text{Average of } \textit{post} \text{ manipulation blink amplitudes}}{\text{Average of } \textit{pre} \text{ manipulation blink amplitudes}}$$

In this way, relative changes in blink amplitudes became the dependant variable, and an independent sample *t*-test was used to assess whether this change ratio differed across groups. As visual inspection of the raw EMG ratios indicated that the distribution was skewed, this was tested using a Shapiro-Wilk test of normality. This test confirmed that assumption of normal distribution was violated: $W = .85$, $p < .01$, and to correct for this issue, the natural log (ln) was taken from the raw EMG ratios. After this operation, the distribution had a symmetric bell shape and Shapiro-Wilk's test confirmed the distribution was no longer skewed ($W = .94$, $p = .12$). An independent sample *t*-test indicated that EMG ratios differed significantly between groups: $t(26) = 2.47$, $p = .01$. The mean EMG ratio for the control group was 0.40, differing significantly from 1 ($t(13) = 6{,}41$, $p < .001$), indicating a substantial decrease in blink amplitude. This effect was substantially smaller for the experimental condition: the EMG ratio for this group stayed as high as 0.83, not differing significantly from 1: $t(14) = 1.01$, $p = .33$. In sum, the EMG data show that the amplitude of the blink reflex as a response to an air puff more than halves over time in a control condition, but when participants are instructed to tic in that time period, there is no such effect. See figure 8 for a graphical depiction of the EMG ratios.

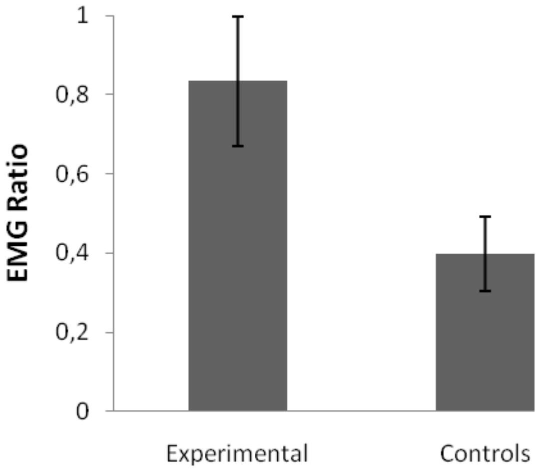

Figure 8: *EMG blink reflex ratios with standard errors of the mean for both conditions.*

For the sake of completeness, the same independent sample *t*-test was calculated using the raw EMG ratios not yet corrected for violations of normality. This yielded a similar result: the raw EMG ratio for the experimental group was greater compared to that of the control group: $t\ (26) = 2.28$, $p = .02$.

Table 3: *Means and standard deviations of the pre & post EMG blink reflex values, and of the blink reflex ratio.*

	Pre	Post	Ratio
Experimental	50,3 (42,5)	38,0 (39,1)	0,83 (0,6)
Controls	61,3 (60,6)	36,7 (59,4)	0,40 (0,4)

Discussion

TS patients have reported that they attempt to neutralize premonitory urges by executing tics. The present data suggest, against hypothesis, that this strategy is effective: after executing tics, there is a decrease in puff annoyance and blink urge compared to a control condition. However, EMG measures suggest that, on a physiological level, this technique backfires by prohibiting a decrease over time in blink reflex amplitude (a decrease that is observed in controls). Possibly then, as Brissaud anticipated (1902), executing tics may be not merely an output phenomenon, but instead an agent in the maintenance or aggravation of tic behaviour. This study suggests that executing a tic in response to an urge may on one hand subjectively reduce this urge, but on the other hand, paradoxically, may sensitize to future urges.

To regard the absence of a decreasing blink reflex as a sensitisation to future premonitory urges in TS may seem like a large conceptual leap. Blink amplitudes did not increase, as hypothesized, but failed to decrease. In an attempt to bridge this gap, it can be hypothesized that participants who executed tics displayed an abnormal pattern of habituation. This idea is not new. Following a] the observation that tic movements somewhat resemble startle reflexes (Corbett, 1967, in Turin, 1983), and b] the suggestion of Clark (1966) that in TS patients startle reflexes may fail to habituate due to a lack of inhibition, two studies tested whether TS patients indeed show abnormal patterns of habituation. However, differences in habituation between TS patients and healthy controls were not found, and both studies were never published (see Turpin, 1983, p210). In the present study, the EMG ratio of controls decreased to below .5, in all probability representing a normal habituation to repeated stimuli. In the experimental group, the EMG ratio did not drop significantly. These findings are compatible with the claim that executing tics is associated with decreased habituation. Crucially, they support the hypothesis that executing tics does in fact *prevent* habituation from taking place.

This hypothesis predicts that TS patients should benefit from any therapy that encourages them to reduce their tic behaviour to a minimum. This seems to be the case: Exposure and Response prevention (ER), featuring nonresponding and exposure to urges as a core treatment component (Hoogduin, Verdellen, & Cath, 1997), has positive effects on TS symptoms (Verdellen, Keijsers, Cath, & Hoogduin, 2004). A second prediction is that ER is effective *because* it acts on these habituation processes (i.e. not only by nonspecific factors), and this also has been established: habituation to unpleasant urges is an key mechanism of change in this therapy when applied to TS patients (Verdellen et al., 2008). In sum, the present results are certainly compatible with the hypothesis that executing tics prevents normal habituation to sensory urges from taking place, and further research might enhance the theoretical understanding of interventions such as ER.

The present study suggests that executing a tic is rewarded by making unpleasant sensations less unpleasant - but exactly how, or why this happens remains unclear. Two possible pathways are suggested. First, the assignment to execute a tic in response to an air puff might have provided participants with a sense of perceived control, thereby making the air puffs more bearable. Participants experienced air puffs as by and large unpleasant (ratings never approached zero on pleasantness or annoyance scales). Additionally, in post-experiment interviews, several participants of the control condition reported that they experienced a build-up of anticipatory tension during the random and unpredictable intervals between air puffs. These statements match the observation that some participants of the control condition showed a slight but fast quivering or trembling of the eyelid in expectance of the next air puff. There were no such reports nor such observations in the experimental condition. In sum, participants in the control condition had to sit back and endure somewhat unpleasant stimuli which were temporally unpredictable. In the experimental condition however, the option to perform a tic may have given participants some degree of perceived control over their situation: instead of passively being subjected to unpleasant stimuli, they were given a tool to handle the situation. This may have added to the overall predictability of the next 'puff-squeeze combination' (at least their own response was self-controlled), as well as to feelings of personal competence (I am prepared, I know what to do). Possibly, such perceived control has mediated subjective ratings. On a purely speculative note, the 'just-right' feelings that TS patients report to result from tics may represent a reflection of this benefit. In further research, subjective measures of to what extend tics offer a degree perceived control while being subjected to irregular stimulus presentation could be collected to investigate this hypothesis.

A second pathway offered to explain the rewarding properties of tics concerns the contrast between the intensity of sensations elicited by the tic on one hand, and by the air puffs on the other hand. The squeezing movements performed during the experimental phase B have almost certainly resulted in strong sensations in the eye, stronger than those elicited by the rather soft air puffs. Conceivably, subsequent air puffs in phase C were unintentionally compared with the salient sensations experienced right before, in phase B. This might have distorted the intended comparison with the puffs in phase A earlier. Technically, this may be regarded as a methodological confound. However, when adding this speculation to the previous argument regarding perceived control, one may argue that TS patients attempt to replace an uncontrollable, unpredictable, and unpleasant urge with a much stronger, but controllable and self-initiated sensation, resulting in a] increased perceived control over the situation as a whole, as well as b] subjective weakening of the original 'premonitory' sensation, simply by contrasting it with a much stronger sensation.

More mundane explanations for the present EMG findings may be put forward. Possibly, the musculus orbicularis oculi 'warmed up' by the repeated squeezing in the experimental condition, leading in some way to greater muscle activity and blink reflexes by the time of post measurement. Alternatively, firm muscle movements might cause the skin to become warmer or wetter, resulting in increased electrical conductivity. Similar explanations may be offered for the results on the VAS scales. Muscle movements themselves might have mediated differences between groups, by for example leading to increased moist on the eyelid, thereby preventing sensations of dryness, which in turn lead to a reduction of an urge to blink. To rule out these physiological explanations, two additional experiments have been carried out in which the current two conditions are repeated, but without actual air puffs coming out of the end of the tip. This yields a 2 (puffs yes/no) x 2(tics yes/no) design. These two experiments have been carried out, and await analysis. Results are expected in mid 2011.

From a historical point of view, the present study is not the first example of tic behaviour being approached from a learning perspective. Yates (1970) has reviewed that such approaches were especially inspired by the observations that tics do not appear during sleep, and that they can to some extend be suppressed at will. One of the first conditioning models of tics was forwarded by Brain (1928), who argued that tic behaviour in children was originally elicited by external stimuli, later rewarded by for example parental reactions. In a similar fashion, tics were later conceptualised as conditioned avoidance reactions, originating from a unconditioned response during a traumatic experience in early childhood (Clark, 1966, Yates, 1958; 1970). Like Brain, these operant conditioning models claimed that tic behaviour is strengthened via social reinforcement, such as increased attention from others (Azrin & Nunn, 1973). Evidence in support of these approaches however is lacking (Turpin, 1983). One of the first to suggest that *internal* processes might play a role in tic behaviur was Turpin (1983), who, referring to Bliss's report about premonitory urges (Bliss, 1980) wrote: *'If it were recognised that tics resulted from an urge to tic, then treatment procedures developed for obsessional-compulsive disorders might be appropriate (...). Clearly, this approach deserves further examination'.* Today, as discussed earlier, exposure and response prevention, established treatment strategies for OCD, are shown to be clinically effective treatment components for TS (Verdellen et al., 2004), rendering Turpin's prediction quite compelling, in retrospect. The present study connects directly to Turpin's ideas, and contributes to the theoretical understanding of these disorders and their interventions.

Two decades ago, it was suggested that the repeated efforts of OCD patients to experience relief from unpleasant feelings have counterproductive results (Salkovskis, 1988, p.40). The present findings suggest that attempts made by TS patients to alleviate unpleasant sensations may have similar paradoxical effects.

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APPENDIX A: Pilot Study.

Introduction
Aim: to test the air puff apparatus custom-built for this experiment, and to establish what duration for the air puffs was best suited to elicit a blink reflex.

Method
Air puffs of varying duration were presented to 5 participants. Puff duration varied from 50 to 500ms, with steps of 50ms. Each participant received 100 puffs, 10 from each puff length category, randomly distributed. For each puff duration, corresponding average EMG amplitudes were calculated.

Results
A repeated-measures ANOVA showed that all puff durations yielded comparable effects on the blink reflex: $F(9,27) = 1.37$, $p = .25$. See also Figure 9 below. It was found that the blink amplitude was considerably smaller than startle reflex amplitudes, which are usually in the 200-300 ηV range.

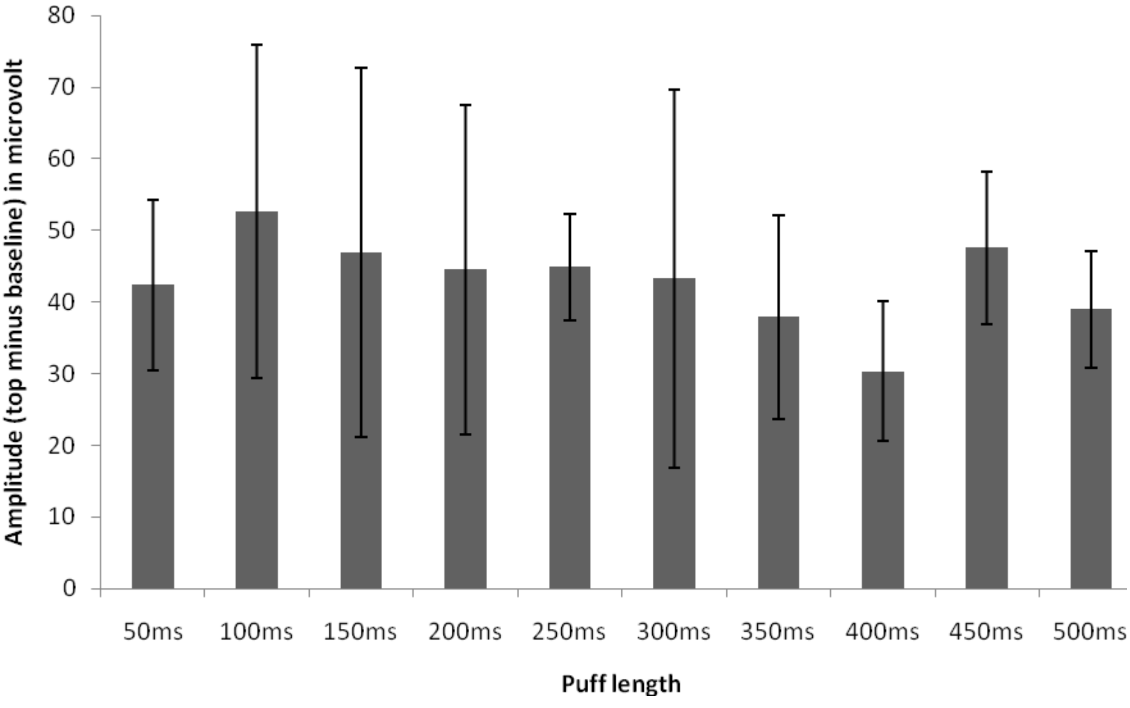
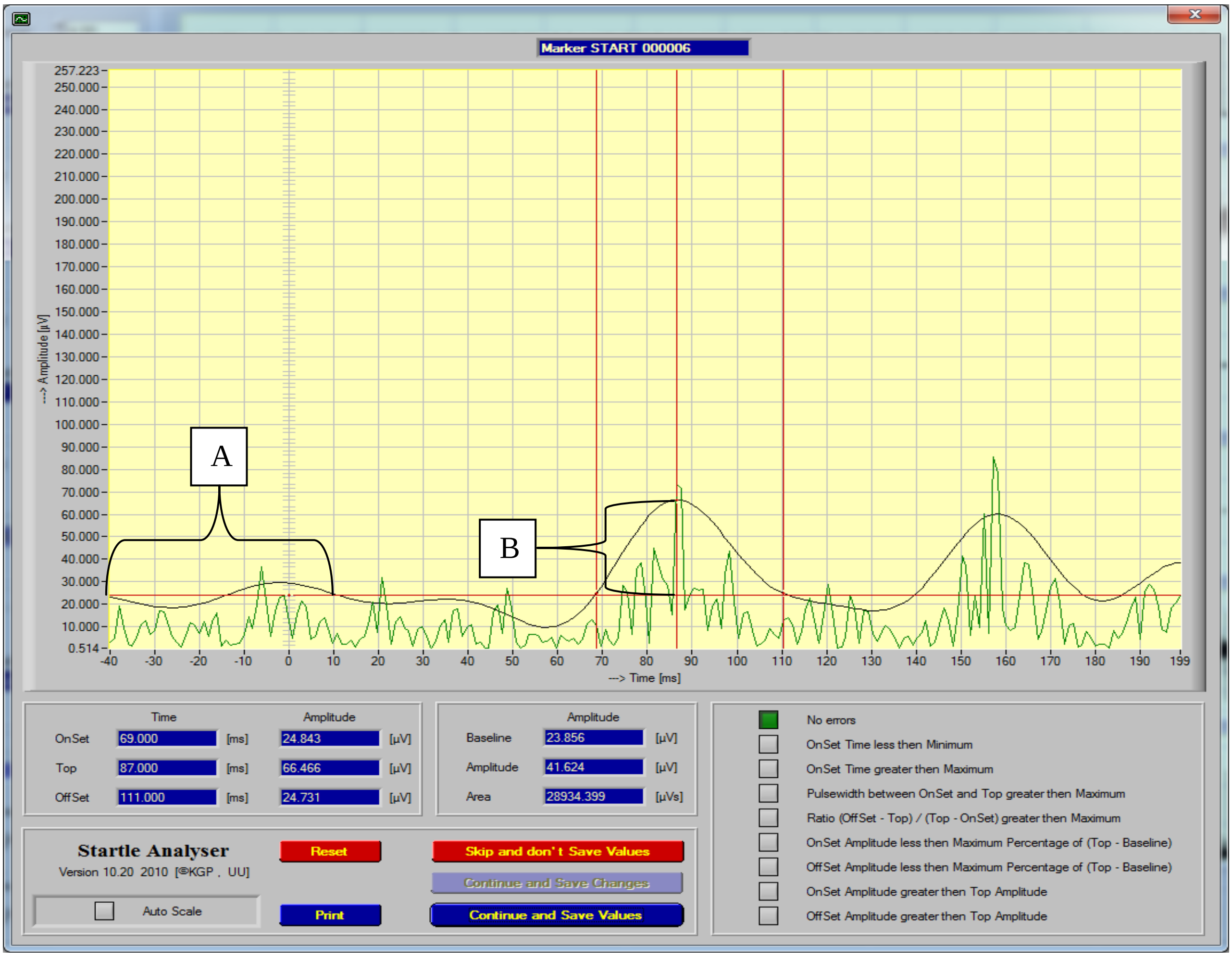


Figure 9: *Average blink reflex amplitude and standard deviation for each pulse duration.*

Discussion
The Puff-O-Matic™ was found to operate to our full satisfaction. Furthermore, puff duration had no effect on blink amplitude. In retrospect, this is a logical outcome since the blink reflex starts at 20-70ms, and based on this fact alone it should not matter in theory which puff duration was chosen. Thus, each puff length was available for use in the subsequent main experiment, and ultimately, a puff duration of 200ms was chosen as stimulus length.

APPENDIX B: Interpreting and quantifying a blink reflex.



A typical eye blink response. The horizontal red line shows the baseline calculated by Startle Analyzer (in this particular scenario it is roughly 25 ηV) by taking the average signal strength of the -40ms / +10ms window (indicated by A) around stimulus onset. The vertical range indicated by B indicates the blink amplitude (which is top (65 ηV) minus baseline (25 ηV) = approximately 40 ηV) used for further calculations. As can be distinguished by looking at the *x*-axis, the typical time window for a blink response is 60-110ms, which corresponds with a so-called *R2 component,* when allowing for 10ms delay within the post-valve tubes of the Puff-O-Matic™. Further to the right (130-180ms) another top can be seen, indicating another eye blink, possibly caused by some remaining sensation in the eye such as dryness. Such subsequent blinks (registered only occasionally) were regarded as noise: only the amplitudes from the blinks starting at about 60ms were used to calculate the ultimate dependent variable: EMG ratio.

APPENDIX C: The distraction picture.

The distraction picture used in the present study. Participants were seated approximately 40cm in front of this picture, which covered a substantial part of their visual field. See the cover page of this manuscript for an in-eye view of the participant from the headrest.

APPENDIX D: VAS questions for subjective ratings. Items in grey: filler items.

Hoe hard vond je de klikjes (indien gehoord)?

|---|

Bijna niet hoorbaar Erg luid

Hoe sterk vond je de geur (indien geroken)?

|---|

Ik heb niets geroken Zeer indringende geur

Hoe vond je de pufjes lucht (indien gevoeld)?

|---|

Helemaal niet onaangenaam Zeer onaangenaam

Hoe *sterk* vond je de pufjes lucht (indien gevoeld)?

|---|

Niet voelbaar Zeer intens

Hoe heb je de pufjes lucht ervaren (indien gevoeld)?

|---|

Helemaal niet storend Behoorlijk storend

Wat vond je van het plaatje?

|---|

Niet interessant Heel interessant

Hoe sterk was de neiging om met de ogen te knipperen (indien pufjes)?

|---|

Geen enkele neiging Erg sterke neiging te knipperen