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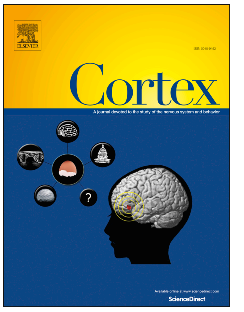

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Triangles, tricks and tics: Hyper-mentalizing in response to animated shapes in Tourette syndrome

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Running head: Hyper-mentalizing in Tourette syndrome

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Abstract

Tourette syndrome (TS) can feature complex tics involving socially inappropriate behaviors. Adults with TS can also demonstrate differences to healthy controls when reasoning about mental states. This study investigated spontaneous mentalizing in TS. Twenty adults with TS and twenty healthy controls completed the animations task. Participants were asked to watch short ambiguous animations involving two triangles and describe what was happening. Some animations featured random movement of the triangles, while others depicted social interactions that were simple (e.g. dancing) or more complex (e.g. one triangle tricking the other). Measures were taken of executive functions, alexithymia and clinical symptoms. Individuals with TS responded similarly to controls when viewing animations featuring simple and complex interactions, demonstrating intact mentalizing ability. However, significant group differences were apparent for the random animations. TS was associated with a greater tendency to attribute mental states during this condition, and to describe random movements as motivated actions guided by the intentions of the triangles. There were no group differences for the alexithymia scale, but TS was associated with mild executive deficits. No relationships were apparent between animation responses and other measures. Our findings suggest that TS is associated with a propensity to adopt the intentional stance. Hyper-mentalizing in TS could be linked to both dopamine dysfunction and altered social behavior, whereby amplified salience of social cues could contribute to the complex interplay between environmental context and tic expression. These observations may offer further insight into the potential effects of dopamine dysfunction on social cognition.

KEY WORDS: Mentalizing; Social Cognition; Theory of Mind; Tics; Tourette syndrome

1. **Introduction**

Tourette syndrome (TS) features tics, repetitive movements and vocalisations, preceded by a sensory-cognitive premonitory urge. Common co-morbid conditions include obsessive-compulsive disorder (OCD) and attention deficit hyperactivity disorder (ADHD). Some of the more interesting complex tics have significant social relevance. These include coprolalia: swearing tics; echo-phenomena: the urge to imitate other people's speech and behavior; and non-obscene socially inappropriate symptoms (NOSIS): urges to perform behaviors which will cause social disruption or offence to others (Cavanna *et al*., 2010; Kurlan *et al*., 1996; Eddy & Cavanna, 2013a&b).

Socially inappropriate tics prompted the study of patients' Theory of Mind (ToM): the ability to reason about mental states such as beliefs and emotions. Studies found that individuals with TS may interpret social stimuli differently to controls, with unconventional interpretations of emotional facial expressions and socially inappropriate or sarcastic remarks (Eddy *et al*., 2010a; Eddy *et al*., 2011). TS is not associated with a straightforward lack of ability in terms of attributing mental states (Eddy & Cavanna, 2013c). However, certain kinds of ToM tasks elicit unconventional interpretations. For example, accidental socially inappropriate faux pas may be interpreted by individuals with TS as intentional acts (Eddy *et al*., 2010b).

This study further explored how individuals with TS reason about social stimuli using an implicit test of ToM. The animations task (AT: Abell *et al*., 2000; Castelli *et al*., 2000) was chosen because of the more ambiguous nature of the stimuli it contains. During the task, participants are faced with a series of video-clips showing the movements of two triangles. In some animations, the movements are random. In others, there is either a simple interaction (e.g. one triangle follows or dances with the other), or a more complex interaction (e.g. one triangle tries to trick or surprise the other triangle). Participants are simply asked to explain what is happening in the video-clips. Healthy individuals are more likely to draw inferences linked to the presence of mental states (e.g. emotions, intentions) in response to video-clips featuring complex interaction, than those animations showing random movements. However, viewers with autism spectrum disorders often fail to draw such higher level inferences (Abell *et al*., 2000). More concrete interpretations that may indicate ToM impairment have also been reported in a range of conditions, from dementia (Gregory *et al*., 2002) to somatoform disorder (Subic-Wrana *et al*., 2010). In schizophrenia, some patients with paranoia over-mentalize and report a higher level of intention in random animations than controls (Russell *et al*, 2006), while others show poorer interpretation of both simple and complex interactions (Horan *et al*., 2009).

It has previously been shown that interpretation of AT video-clips can be linked to alexithymic characteristics (Moriguchi *et al*., 2006), which encompass difficulties in describing feelings, or in disentangling emotions from physical states (Taylor *et al*., 1988). This association may arise because the assignment of mental states to external stimuli may be linked to analytical abilities based on internal experience. In a similar vein, mood disorder can influence AT interpretations. For example, Ladegaard *et al*., (2014) demonstrated that major depression was associated with decreased mentalizing in response to the AT. However, executive dysfunction was an additional factor in this study. While fairly minor cognitive difficulties are reported in TS (e.g. Eddy *et al*., 2009), limitations in e.g. memory or attention deficits could affect performance on the AT. In the current study, we therefore investigated relationships between AT responses, alexithymia and executive functions. Based on previous studies of ToM in TS, we hypothesised that individuals with TS may show less conventional interpretations of the AT clips when compared to controls. We further hypothesised that AT responses would be related to scores on the alexithymia scale. Although previous studies have highlighted emotional differences in TS including affective dysregulation (e.g. Martino et al., 2013), this could be the first study to use the Toronto Alexithymia Scale in this population.

2. Method

2.1 Participants

The study was approved by the local NHS research ethics committee and all volunteers provided written informed consent. Twenty adults with TS according to DSMV criteria (17 males) volunteered to participate and were screened using the National Hospital Interview Schedule for TS (Robertson & Eapen, 1996). Mean age was 35 years (SD=16; median=32; range=19-68) and mean years of education was 14.01 (SD=3.09; median=13; range=11-19). A few patients reported co-morbid OCD (n=4) or mood disorders (n=2). Fifteen patients were taking medications (atypical antipsychotic=9; SSRI=2; clonidine=3; tricyclic anti-depressant=1). All patients who were taking medications were stable on these medications for at least 6 months prior to testing. YGTSS motor tic ratings were quite high in terms of frequency (mean score 3.75; SD=1.07; median=4; range=1-5), intensity (mean 3.45; SD=1.00; median=4; range=1-5) and complexity (mean 3.25; SD=0.97; median=3; range=1-5). Phonic tics were of moderate frequency (mean 2.55; SD=1.19; median=3; range=1-4), intensity (mean 2.65; SD=1.04; median=3; range=1-4) and complexity (mean 2.90; SD=1.83; median=2.5; range=1-5). Most patients scored similarly for their motor and phonic tics. Ten adults with TS reported NOSIS, 13 reported echo-phenomena and 12 reported copro-phenomena (these features commonly co-occurred in the same patients). Twenty healthy controls (17 males) of mean age 34.60 years (SD=15.02; median=28.5; range=18-65) and mean education 14.55 years (SD=1.82; median=14.00; range=13-19) also participated. Healthy volunteers were only invited to participate if they did not have any psychiatric or neurological diagnoses, and were not taking any psychoactive medications. The groups did not differ for years of age (MWU=196.5, p=.925) or education (MWU=226.5, p=.478).

All participants completed the AT, three executive tasks and the Toronto Alexithymia Scale (TAS). Patients with TS also completed scales assessing tics, OCD, ADHD, anxiety and depression. Yale Global Tic Severity Scale (YGTSS: Leckman *et al*., 1989) tic score was mean 30.05 (SD=8.10). Mean Obsessive-Compulsive Inventory Revised (Foa *et al*., 2002) scores were 23.40 (SD=14.59). Mean scores on the Adult Self-Report ADHD Scale (Kessler *et al*., 2005) were 11.45 (SD=5.61). Mood disorder was rated using the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) and mean scores were 10.70 for anxiety (SD=4.69) and mean 11.45 (SD=5.61) for depression.

2.2 Tasks

2.2.1 Animations Task (AT)

This task (Abell *et al*., 2000; Castelli *et al*., 2000) consists of 12 animations, each lasting approximately 30-40 seconds. All video-clips feature a big red triangle and a small blue triangle. There are three different types of animations: random movements, goal-directed movements (GD) and movements depicting complex interactions that prompt ToM (see Figure 1). Four of each type are presented. Participants watch each video-clip on a computer monitor and simply explain what was happening on screen. The video-clips was presented in a mixed order, consistent across participants. If a participant had failed to speak by the time the video-clip had almost finished, they were prompted with "what's happening?" or "tell me what you are thinking". Specific feedback was not given in relation to response content, but positive encouragement was offered. Two raters scored participants' responses for appropriateness, intentionality and word length using the developers' coding system (Abell *et al*., 2000; Castelli *et al*., 2000). For appropriateness, scores ranged from 0 (no relevant description) to 2 (a response demonstrating understanding of all key features of the interaction with reference to mental states where appropriate). Intentionality was scored based on the presence of specific terms given by the developers (e.g. 4 point answers contained mental state terms and 5 point answers contained descriptions of an intention held by a triangle to influence the mental state of the other triangle, such as surprising). Response length was scored from 0-4 based on the number of clauses. One rater was blinded to participant group to reduce bias. Averages were used when raters did not reach complete agreement. Inter-rater agreement for length, intention, and accuracy scores on the AT was very good (Cohen's kappa: length=0.81; intention=0.82; accuracy=0.84).

2.2.2 Toronto Alexithymia Scale (TAS)

The TAS (Taylor *et al*., 1988) contains 26 statements. Participants rate their agreement with each using a 5-point Likert scale (strongly disagree; disagree; neither agree nor disagree; agree; strongly agree). Higher scores indicate more alexithymia. The threshold for alexithymia is around 62, although a more conservative cut-off of 74 yields greater diagnostic confidence. The TAS demonstrates excellent psychometric properties including validity (Taylor *et al*., 1990).

2.2.3 Trail Making Test (TMT)

Participants were presented with a page containing 25 small circles each containing a number from 1 to 25 (Reitan & Wolfson, 1958). They were required to join the circles with a line in ascending order (i.e. 1–2, 2–3). For the second part of the task, there were 24 circles containing the numbers 1–12 and the letters A to L. For this part, participants were asked to join the circles alternating from number to letter, ascending in both categories (i.e. 1 to A, A to 2, 2 to B). Short demonstrations were given before testing. Errors were indicated for correction, and time taken was recorded for each condition, to generate a score to reflect the difference.

2.2.4 Digit Ordering Test-Adapted (DOT-A)

Participants listened to individual streams of digits (Werheid *et al*., 2002; Cooper *et al*., 1991) before rearranging the digits and saying them back in ascending order. Streams increased from 3 to 8 digits over testing. A pair of streams was presented of each length. The maximum span was the longest stream to which participants could respond. Participants who only responded correctly to one stream of a single length had 0.5 points deducted from their maximum span.

2.2.5 Hayling Test

For the baseline condition, the experimenter read sentences that cue a final word (Burgess & Shallice, 1996), and participants were asked to complete each sentence with an obvious word. For the test condition, the sentences still cued particular words, but participants were asked to avoid saying the word that seems most obvious and use a different word. Inhibition was assessed by comparing both time and error differences across conditions.

2.2.6 Yale Global Tic Severity Scale (YGTSS)

This clinician rated scale (Leckman *et al*., 1989) assesses overall tic severity. Motor and vocal tics are scored in terms of tic number, frequency, complexity, intensity and interference.

2.2.7 Obsessive Compulsive Inventory-Revised (OCI-R)

OCD symptoms can be assessed using this 18-item, self-report, 5-point likert scale (Foa *et al*., 2002). Higher scores indicate more severe symptoms.

2.2.8 Adult ADHD Self-Report Scale (ASRS)

The current study used a subset of six questions from the original ADHD scale, which have been shown to outperform the full scale in diagnosing ADHD in adults (Kessler *et al*., 2005).

2.2.9 Hospital Anxiety and Depression Scale (HADS)

This scale (Zigmond and Snaith, 1983) consists of 7 items to assess depression, and seven to measure anxiety. Analysis used totals for each subscale.

2.3 Statistical analyses

Data were tested for normality using skewness and kurtosis values and Shapiro-Wilk Test, which indicated that eleven of the sixteen variables were clearly not normally distributed, therefore non-parametric Mann Whitney-U tests were applied for between-group comparisons. Stepwise linear regression was also used to explore whether clinical factors were predictive of task performance in the patient group.

3. Results

There were mild differences between the groups for working memory span and sustained attention/switching on the trial making task, but TS was not associated with more errors or longer time differences on the Hayling Test (Table 1). These group-differences would not survive correction for multiple comparisons. TAS total scores were also not significantly different for the patient and control groups. One patient and one control scored above the threshold value that indicates alexithymia.

For the AT, individuals with TS and healthy controls provided answers of a similar length for all animation types. Intention ratings were significantly higher for the TS group for the random video-clips and appropriateness scores were significantly lower for the TS group for these animations. Example responses are shown in Table 2. For the goal-directed video-clips, there were emerging trends for higher ratings of intentionality in TS and less appropriate answers. There were no differences between the groups for ToM video-clips. The group differences for random video-clips would survive strict correction for multiple comparisons (i.e. Bonferroni).

Stepwise linear regression analyses explored whether AT random video-clips intention ratings and appropriateness ratings for the TS group could be predicted by executive measures that differentiated between patients and controls (i.e. DOT-A and TMT scores) or clinical factors (scores for tic severity, OCD, ADHD, anxiety and depression; the presence or absence of dopaminergic medication; NOSIS; echo-phenomena; copro-phenomena). No significant models were found. Similarly, age and disease duration were not found to have significant associations with these AT ratings.

Finally, to explore whether the mentalizing differences may be linked to the presence of NOSIS, AT ratings were compared for patients with (n=10) and without (n=10) NOSIS. No significant differences were found.

4. Discussion

Individuals with TS exhibited a pattern of performance consisting of typical responses to goal-directed animations and ToM animations, but unconventional interpretations when viewing random movement. These unusual descriptions were characterised by a tendency to attribute mental states to the triangles, and to conclude that their movements were intentional. This pattern of responses is different to people with autistic spectrum disorders, who answer similarly to controls for random and goal-directed movement, while showing differences in response to ToM video-clips (e.g. Abell *et al*., 2000). Other groups, including patients with schizophrenia, can exhibit poorer performance on ToM video-clips or on all types of clip (Russell *et al*., 2006). For example, individuals with the inherited movement disorder Huntington's disease, which involves striatal degeneration, respond normally to random movement animations but are less likely than healthy controls to apply ToM when describing animations depicting social interaction (Eddy & Rickards, 2015). The pattern of preserved performance on ToM and goal-directed animations in TS coupled with increased attribution of intentions to randomly moving stimuli is therefore quite distinctive.

Some of TS patients' responses on the AT may look similar to those of patients with schizophrenia. Russell *et al* (2006) reported poorer accuracy on all animations including random video-clips, due to individuals with schizophrenia reporting interaction or using mental state terms inappropriately in the random condition. The tendency to hyper-mentalize and over-attribute intentions may occur in paranoid schizophrenia in association with increased tonic dopamine (Abu-Akel & Shamay-Tsoory, 2013). The underlying mechanism is thought to be hyper-salience as a result of elevated dopamine levels, whereby stimuli are perceived as having misplaced emphasis, prompting inferences of abnormal meaning (Howes & Kapur, 2009). In this way, dopamine dysfunction may lead patients to see patterns that other people do not perceive, draw conclusions on less information, and report false-positives in ambiguous situations (Grant *et al*., 2014). None of the patients with TS in the current study exhibited clinical signs of paranoia or associated disorders. However, paranoia *per se* may not be the link explaining the similar performance of these patient groups, but rather another common underlying factor. Like schizophrenia, TS is thought to involve dopamine dysfunction, given the observation that tics can be ameliorated by dopamine antagonists (e.g. Eddy et al., 2011). About half of the TS patients in the current study were taking dopamine antagonists. Nevertheless, it is possible that elevated levels of dopamine could be linked to patients' unconventional responses to the video-clips featuring random movement.

One recent study showed that individuals with TS may demonstrate a tendency to jump to conclusions during a probabilistic reasoning task (Eddy & Cavanna, 2014). That is, adults with TS tended to require less information than controls before making a decision based on probability, and this was associated with obsessive-compulsive symptoms. Taking together these findings, and those of the current study, it seems that the reasoning style associated with TS may be associated with a tendency to 'go too far' or to 'jump the gun' when drawing inferences. Such a cognitive style could involve over-analysis or preoccupation with detail, and go hand-in-hand with characteristics of OCD (e.g. Robertson & Cavanna, 2007). Alternatively, this could be viewed as an impulsive style of responding.

On the AT, individuals with TS demonstrated a propensity towards the intentional stance and to anthropomorphise, i.e. to see the AT triangles as if they were human agents with mental worlds. Epley *et al* (2007) suggest that anthropomorphising in general may stem from factors such as uncertainty avoidance, desire for control, need for closure and social disconnection (Epley *et al*., 2007). The recommended OCI-R cut-off for a likely presence of OCD is a score of 21 (Foa et al., 2002), and 11 patients scored at or above this. Therefore, there was quite a high incidence of OCD symptoms in the patients tested, which is typical for TS samples. Seven patients with TS exhibited ASRS scores which could indicate ADHD. However, these patients still performed quite well on the executive tasks, and some items on the ASRS may measure factors that are intrinsic to tics (e.g. poor concentration because of tic suppression). Although correlational analysis did not indicate a relationship between scores on these scales and responses on the AT, further research is needed to confirm whether hypermentalizing is linked to TS *per se*.

We explored executive function, alexithymia and mood disorder as other possible predictive factors of patients' responses to random movement animations. For example, it could be that the individuals with TS in the current study were less restrained in their interpretations which could indicate a lack of inhibition; or emotional reactivity could be apparent in association with hyper-mentalizing (e.g. Sharp *et al*., 2013). It is possible that patients' responses on the AT were linked to impulsivity. While we did find that TS was associated with mild executive deficits, these were not prominent on the response inhibition measure, and executive performance was not predictive of unconventional AT responses. Neither were ratings for common co-morbid conditions (OCD and ADHD), anxiety, depression and alexithymia, so our second hypothesis was not supported. Including behavioural measures of impulsivity in future research could offer further insight.

An important limitation of the current study is the possibility that our findings reflect some increased level of suggestibility in TS. For example, perhaps these individuals were more motivated than controls to respond creatively to the tasks presented to them. However, the order of presentation of stimuli on the AT was the same for patients and controls, so any influence of expectation due to order effects should have been at least partly controlled for. The possibility that larger samples or particular subgroups of patients (e.g. unmedicated patients; those with co-morbidities etc.) may show differences on the TAS cannot be ruled out. Healthy controls did not complete the OCD or ADHD measures, so this may be considered a limitation. Other limitations include small sample size and heterogeneity in relation to factors such as obsessive-compulsive symptoms and medication. Anti-psychotics may have the potential to affect performance on tests of social cognition, though studies are only available in schizophrenia (e.g. Tyson et al., 2006). Future research comparing the mentalizing styles of TS patients on and off medication may help determine whether differences in social reasoning in TS are state or trait dependent.

The findings presented here expand our understanding of social cognition in TS by implying that hyper-mentalizing can be a facet of this condition. This is not the first study to show increased attribution of intentions in TS. For example, Eddy *et al*. (2010b) reported increased attribution of intent to story characters making socially inappropriate remarks on the faux pas task. Hyper-mentalizing in TS may be most significant in relation to the complex environmentally dependent socially relevant tics. TS can be associated with urges to perform dangerous actions e.g. to touch hot or sharp objects (e.g. Cohen & Leckman, 1992). NOSIS are 'socially dangerous' when the mental states of other people (e.g. negative emotional reactions) are taken into account. The awareness of detrimental actions may possess increased salience in TS, which along with impulse dyscontrol, may contribute to these dangerous tics. That is, a combination of thinking too much about the mental states of other people, and being unable to inhibit impulses could help to explain why some people with TS experience NOSIS (Eddy & Cavanna, 2013a,c).

In relation to a proposed neural basis for our findings, mentalizing during the AT has been linked to activation of the medial prefrontal cortex, temporo-parietal junction, superior temporal sulcus and temporal pole (Castelli *et al*., 2000; Moriguchi *et al*., 2006). However, a role for dopamine dysfunction could implicate additional regions. For example, in individuals at high risk of psychosis, the effect of increased salience due to altered dopamine transmission has been suggested to involve functional alterations in the striatum and hippocampus (Roiser *et al*., 2013). Previous studies have indicated structural changes in regions including the prefrontal and temporal cortices, as well as the striatum, in TS (e.g. Draganski *et al*., 2006). There are also reports of extrastriatal dopamine dysfunction in these patients (Steeves *et al*., 2010).

In conclusion, our findings indicate that individuals with TS can show an increased tendency to mentalize when confronted by ambiguous visual stimuli in the form of randomly moving shapes. TS may therefore be associated with a propensity to adopt the intentional stance. This could in turn suggest an altered perception of agency, which merits further investigation. Further research should explore the relationship between hyper-mentalizing, dopamine dysfunction, impulsivity and altered social behavior, to determine whether amplified salience of social cues could contribute to the complex interplay between environmental context and tic expression.

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Conflict of interest

None.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

References

Abell, F., Happé, F., & Frith, U. (2000). Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. *Journal of Cognitive Development, 15,* 1-20.

Abu-Akel, A., & Shamay-Tsoory, S. (2011). Neuroanatomical and neurochemical bases of theory of mind. *Neuropsychologia, 49,* 2971-2984.

Burgess, P.W., & Shallice T (1996). Response suppression, initiation and strategy use following frontal lobe lesions. *Neuropsychologia, 34,* 263-272.

Castelli, F., Happe, F., Frith, U., & Frith, C. (2000). Movement and mind: a functional imaging study of perception and interpretation of complex intentional movement patterns. *NeuroImage, 12,* 314-325.

Cavanna, A.E., Ali, F., Leckman, J.F., & Robertson, M.M. (2010). Pathological laughter in Gilles de la Tourette syndrome: an unusual phonic tic. *Movement Disorders, 25,* (13), 2233-2239.

Cohen, A.J., & Leckman, J.F. (1992). Sensory phenomena associated with Gilles de la Tourette's syndrome. *Journal of Clinical Psychiatry, 53(9),* 319-23.

Cooper, J.A., Sagar, H.J., Jordan, N., Harvey, N.S., & Sullivan, E.V. (1991). Cognitive impairment in early untreated Parkinson's disease and its relationship to motor disability. *Brain, 114,* 2095-2122.

Draganski, B., Martino, D., Cavanna, A.E., Hutton, C., Orth, M., Robertson, M.M., Critchley, H.D., & Frackowiak RS (2010). Multispectral brain morphometry in Tourette syndrome persisting into adulthood. *Brain*, 133(12), 3661-3375.

Eddy, C.M., & Cavanna, A.E. (2013)c. Altered social cognition in Tourette syndrome: nature and implications. *Behavioural Neurology, 27,* 15-22.

Eddy, C.M., & Cavanna, A.E. (2014). Do patients with Tourette syndrome jump to conclusions? *Journal of Neuropsychiatry and Clinical Neurosciences, 26,* 396-399.

Eddy, C.M., Cavanna, A.E. (2013)b. 'It's a curse!': coprolalia in Tourette syndrome. *European Journal of Neurology, 20(11),* 1467-1470.

Eddy, C.M., & Cavanna, A.E. (2013)a. On being your own worst enemy: an investigation of socially inappropriate symptoms in Tourette syndrome. *Journal of Psychiatric Research, 47(9),* 1259-1263.

Eddy, C.M., Mitchell, I.J., Beck, S.R., Cavanna, A.E., & Rickards, H. (2011). Social reasoning inTourette syndrome. *Cognitive Neuropsychiatry, 16(4),* 326-347.

Eddy, C.M., Mitchell, I.J., Beck, S.R., Cavanna, A.E., & Rickards, H.E. (2010)b. Altered Attribution of Intention in Tourette's Syndrome. *Journal of Neuropsychiatry and Clinical Neurosciences, 22(3),* 348-51.

Eddy, C.M., Mitchell, I.J., Beck, S.R., Cavanna, A.E., & Rickards, H.E. (2010)a. Impaired comprehension of nonliteral language in Tourette syndrome. *Cognitive and Behavioural Neurology, 23(3),* 178-184.

Eddy, C.M., & Rickards, H.E. (2015). Interaction without intent: The shape of the social world in Huntington's disease. *Social Cognitive and Affective Neuroscience doi:10.1093/scan/nsv012.*

Eddy, C.M., Rickards, H.E., & Cavanna, A.E. (2011). Treatment strategies for tics in Tourette syndrome. *Therapeutic Advances in Neurological Disorders*, *4(1)*, 25-45.

Eddy, C.M., Rizzo, R., & Cavanna, A.E. (2009). Neuropsychological aspects of Tourette syndrome: a review. *Journal of Psychosomatic Research, 67(6),* 503-513.

Epley, N., Waytz, A., & Cacioppo, J.T. (2007). On seeing human: A three-factor theory of anthropomorphism. *Psychological Review, 114(4),* 864-886.

Foa, E.B., Huppert, J.D., Leiberg, S., Langner, R., Kichic, R., Hajcak, G., & Salkovskis, P.M. (2002). The obsessive compulsive inventory: development and validation of a short version. *Psychological Assessment, 14,* 485-496.

Grant, P., Balser, M., Munk, A.J., Linder, J., & Hennig, J. (2014). A false-positive detection bias as a function of state and trait schizotypy in interaction with intelligence. *Frontiers in Psychiatry, 5,* 135.

Gregory, C., Lough, S., Stone, V., Erzinclioglu, S., Martin, L., Baron-Cohen, S., & Hodges, J.R. (2002). Theory of mind in patients with frontal variant frontotemporal dementia and Alzheimer's disease: theoretical and practical implications. *Brain, 125,* 752-764.

Horan, W.P., Nuechterlein, K.H., Lee, J., Castelli, F., & Green, M.F. (2009). Disturbances in the spontaneous attribution of social meaning in schizophrenia. *Psychological Medicine, 39(4),* 635-643.

Howes, O.D., & Kapur, S. (2009). The dopamine hypothesis of schizophrenia: version III-the final common pathway. *Schizophrenia Bulletin, 35(3),* 549-562.

Kessler, R.C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E., Howes, M.J., Jin, R., Secnik, K., Spencer, T., Ustun, T.B., & Walters, E.E. (2005). The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. *Psychological Medicine, 35,* 245-256.

Kurlan, R., Darajati, C., Como, P.G., McDermott, M.P., Trinidad, K.S., Roddy, S., Brewer, C.A., & Robertson, M.M. (1996). Non-obscene complex socially inappropriate behavior in Tourette syndrome. *Journal of Neuropsychiatry and Clinical Neurosciences, 8,* 311-317.

Leckman, J.F., Riddle, M.A., Hardin, M., Ort, S.I., Swartz, K.L., Stevenson, J., & Cohen, D.J. (1989). The Yale global tic severity scale: initial testing of a clinician-rated scale of tic severity. *Journal of the American Academy of Child and Adolescent Psychiatry, 28,* 566-573.

Martino, D., Madhusudan, N., Zis, P., & Cavanna, A.E. (2013). An introduction to the clinical phenomenology of Tourette syndrome. *International Reviews in Neurobiology, 112,* 1-33.

Moriguchi, Y., Ohnishi, T., Lane, R.D., Maeda, M., Mori, T., Nemoto, K., Matsuda, H., & Komaki, G. (2006). Impaired self-awareness and theory of mind: an fMRI study of mentalizing in alexithymia. *Neuroimage, 32,* 1472-82.

Reitan, R.M., & Wolfson, D. (1985). *The Halstead-Reitan neuropsychological test battery: therapy and clinical interpretation*. Neuropsychological Press: Tucson.

Roiser, J.P., Howes, O.D., & Chaddock, C.A., Joyce, E.M., & McGuire, P. (2013). Neural and behavioural correlates of aberrant salience in individuals at risk for psychosis. *Schizophrenia Bulletin, 39(6),* 1328-36.

Robertson, M.M., & Cavanna, A.E. (2007). The disaster was my fault! *Neurocase, 13(5),* 446-451.

Russell, T.A., Reynaud, E., Herba, C., Morris, R., & Corcoran, R. (2006). Do you see what I see? Interpretations of intentional movement in schizophrenia. *Schizophrenia Research, 81(1),* 101-111.

Sharp, C., Ha, C., Carbone, C., Kim, S., Perry, K., Williams, L., & Fonagy, P. (2013). Hypermentalizing in adolescent inpatients: treatment effects and association with borderline traits. *Journal of Personality Disorder, 27,* 3-8.

Steeves, T.D., Ko, J.H., Kideckel, D.M., Rusjan, P., Houle, S., Sandor, P., Lang, A.E., & Strafella, A.P. (2010). Extrastriatal dopaminergic dysfunction in tourette syndrome. *Annals of Neurology, 67(2)*, 170-181.

Subic-Wrana, C., Beutel, M.E., Knebel, A., & Lane, R.D. (2010). Theory of mind and emotional awareness deficits in patients with somatoform disorders. *Psychosomatic Medicine, 72(4),* 404-411.

Taylor, G.J., Bagby, R.M., Ryan, D.P., & Parker, J.D. (1990). Validation of the alexithymia construct: a measurement-based approach. *Canadian Journal of Psychiatry, 35(4)*, 290-297.

Taylor, G.J., Bagby, R.M., Ryan, D.P., Parker, J.D., Doody, K.F., & Keefe, P. (1988). Criterion validity of the Toronto Alexithymia Scale. *Psychosomatic Medicine, 50(5),* 500-509.

Tyson, P.J., Laws, K.R., Flowers, K.A., Tyson, A., & Mortimer, A.M. (2006). Cognitive function and social abilities in patients with schizophrenia: relationship with atypical antipsychotics. *Psychiatry and Clinical Neurosciences*, *60(4)*, 473-479.

Werheid, K., Hoppe, C., Thone, A., Muller, U., Mungersdorf, M., & Yves von Cramon, D. (2002). The adaptive digit ordering test: clinical application, reliability, and validity of a verbal working memory test. *Archives of Clinical Neuropsychology, 17,* 547-565.

Zigmond, A.S., & Snaith, R.P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica, 67,* 361-370.

Table 1. *Task performance for patients with Tourette syndrome and healthy controls*

Measure	Adults with Tourette syndrome				Healthy controls				Statistics	
	Mean	SD	Median	Range	Mean	SD	Median	Range	MWU	p-value
DOT-A	5.45	1.02	5.25	4-8	5.98	0.80	6.00	4.5-7	277	.038
TMT	40.08	29.52	26.82	10.06-127.36	21.62	10.99	19.84	3.78-48.18	115	.021
Hayling error difference	0.38	0.58	0	0-2	0	0	0	0	32.5	.243
Hayling time difference	15.73	9.14	15.71	1.75-24.87	15.60	14.96	6.70	3.45-38.63	46	.818
TAS	56.00	12.28	53.5	38-80	50.70	15.29	52.00	23-83	161	.301
AT Ran Int	4.35	3.65	3.5	1-13	0.80	0.95	0.50	0-3	45	<.001
AT Ran App	5.40	2.04	5.25	1.5-8	7.43	0.82	8.00	5-8	329	<.001
AT Ran Len	10.18	3.09	10.50	5-14	10.90	2.27	11.00	8-15	224	.529
AT GD Int	10.55	2.41	10.25	7-14	9.33	1.55	9.00	6-12	133.5	.072
AT GD App	6.78	1.03	7.00	5-8	7.38	0.70	7.50	6-8	267	.072
AT GD Len	12.05	2.75	13.00	7-16	12.28	2.12	12.00	9.5-16	200	1.000
AT ToM Int	16.28	2.05	16.50	13-20	16.15	2.00	16.00	12.5-19	192	.841
AT ToM App	6.18	1.04	6.25	5-8	6.30	1.30	6.00	4-8	209.5	.799
AT ToM Len	13.78	2.23	15.00	9-16	14.50	1.64	14.00	11-16	240.5	.277

KEY: AT: Animations task; App: appropriateness score; DOT-A: Digit ordering test-adapted; GD: goal-directed simple interaction animations; Int: Intention score; Len: length score; MWU: Mann Whitney U test statistic; Ran: random animations; TAS: Toronto Alexithymia Scale; TMT: Trail Making Test; ToM: theory of mind complex interaction animations.

Table 2. *Example response of adults with Tourette syndrome and healthy controls to animations task video-clips featuring random movement*

Tourette syndrome	Healthy controls
• "The blue is an infant or child, red is like an adult… copying each other? Blue is trying to get to know the red and the red is not having it!" • "They are chasing each other, nearly got to each other, turned away."	• "Just bouncing around, nothing else, just bouncing around inside a big square." • "Moving around, seems random, bouncing in corners, now close, now passing each other: passing each other closely."
• "They're like little ghosts, it's like they are playing tag… they nearly got in the box… like one is an adult and one is a child." • "There's a box in the middle and the red and blue triangles are looking to enter the box but don't know how. The little one is quirky so has more chance to get in, but can't seem to find a way…"	• "Both triangles moving around, there's a square with a line missing on the side… changing directions, narrowly missing each other, not touching the walls" • "Triangles again, a building in the middle, going close, drifting, going clockwise and counter-clockwise."
• "It's like two drunk triangles, in space, I'm sure they're trying to get in the box!" • "Flirting again, fell out now, bouncing off the house, they had a massive bust up, not acknowledging each other, they don't care so not worried at all."	• "They're both bouncing around the edges, no particular direction, one clockwise and one anticlockwise, hitting the walls and the box. They keep doing that over and over again." • "Just bouncing around lifelessly (before they seemed to have their own minds), just bouncing around."
• "One on the top and one on the bottom, as though they're cutting the grass. Sharing something… one is taking responsibility." • "Sliding back and forth, like they're protecting their own area, like sentries, getting closer? Gone back… they're testing each other."	• "Bouncing off sides of the box, small at the top and large at the bottom, staying in that form, narrowly missing square, changing direction as they come off the wall." • "They're both just moving horizontally across the screen, staying in their third of the screen."

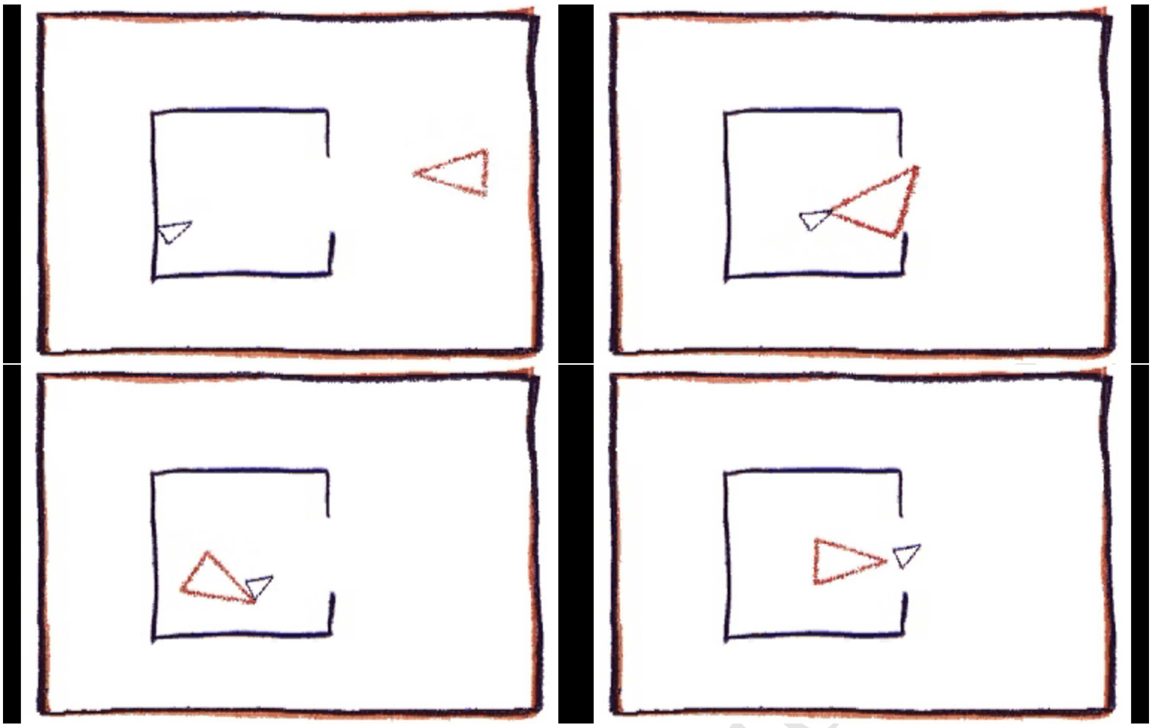

Figure 1. In this animation involving complex interaction, the large red triangle appears to coax the small blue triangle out of an enclosure, prompting attribution of mental states e.g. the blue triangle is scared and the red triangle is trying to encourage it to leave the box (Abell et al., 2000)