neuroscience reveals multiple memory systems that are each associated with different neural substrates [5].

Our arguments are also applicable to other dissociations beyond the ones discussed by Amodio. For example, several studies have found that implicit (i.e., spontaneous) evaluations reflect the mere co-occurrence of stimuli regardless of their relation, whereas explicit (i.e., deliberate) evaluations are sensitive to the particular relation of the co-occurring stimuli [6]. Based on extant dual-process theories, such findings have been interpreted as evidence for distinct learning mechanisms underlying implicit and explicit evaluations: automatic formation of associative links between co-occurring events (e.g., associative link between A and B) and controlled generation and truth assessment of mental propositions about the relation between co-occurring events (e.g., A prevents B). However, the observed dissociation may also reflect differences in the retrieval of stored propositional information, given that (i) implicit and explicit evaluations differ in terms of their relative speed and (ii) fast evaluations are more likely affected by incomplete retrieval of stored information (e.g., retrieval of A is related to B rather than A prevents B) [7]. Thus, different from the argument that the observed dissociation provides evidence for functionally distinct learning mechanisms, it can be explained by retrieval-related processes without any assumptions about distinct learning mechanisms or distinct memory systems.

When exploring complexity in the retrieval and use of stored information, social cognition research can draw upon an extensive literature in diverse fields of psychology and neuroscience. For example, a wide range of phenomena such as categorization, task switching, recognition, recall, contingency learning, feature binding, stimulus–response binding, negative priming, and social judgment can be accounted for by episodic memory models that assume a single (episodic) memory system that is operated upon by context-dependent similarity-based retrieval mechanisms [8–10]. Likewise, many complexities of Pavlovian conditioning can be accounted for by assuming a comparator mechanism that compares multiple simple associations at the time of performance [11]. Finally, cognitive neuroscience has seen a surge in the popularity of predictive coding models, which explain a wide range of behavioral findings in terms of highly flexible processes involved in the retrieval and expression of low-level predictions [12]. Social cognition researchers are only beginning to exploit the huge potential that these retrieval-based approaches offer. Following this shift towards explaining behavioral complexity at the level of retrieval might be a more promising way forward for social cognition than a proliferation of learning and memory systems.

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Forum

Obsessive Compulsive Disorder: A Pathology of Self-Confidence?

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Heleen A. Slagter [4,5,6] and
Damiaan Denys [1,4]

A striking change OCD patients repeatedly describe following treatment with deep brain stimulation (DBS) of the ventral anterior limb of internal capsule (vALIC) is an immediate increase in self-confidence. We show how the DBS-induced changes in self-confidence reported by our patients can be understood neurocognitively in terms of active inference.

Deep Brain Stimulation (DBS) Increases Self-Confidence

Patients with obsessive compulsive disorder (OCD) experience unwanted intrusive thoughts ('obsessions') expressive of their anxious mode of relating to the world. They feel strong urges to repeatedly perform ritual-like behaviours ('compulsions'). Our group at the Amsterdam University Medical Center currently treats 80 treatment-refractory OCD patients with DBS, an innovative treatment method in which a 'neurostimulator' is surgically implanted, providing stimulation to areas deep in the brain. In our OCD patients, stimulation is applied to areas located in the ventral striatum, near the ventral anterior limb of the internal capsule (vALIC)/nucleus accumbens. In the first placebo-controlled clinical study published on striatal-DBS for OCD, our group demonstrated a 72% symptom reduction in responders [1]. In contrast to regular drug treatments, OCD patients responded to DBS immediately (sometimes within seconds to minutes) when adequate stimulation parameters were identified.

One of the most striking changes patients repeatedly describe, both in the clinic and in qualitative interviews we carried out [2], is an immediate and persisting increase in self-confidence. Simultaneously, patients report a reduction in anxiety-related obsessions, while improvement in compulsivity symptoms typically requires additional behavioural therapy. In this article, we propose that the primary effect of DBS may be to increase the patient's self-confidence. Our hypothesis is based in part on clinical observation and qualitative interviews we conducted [2]. Furthermore, we have observed that when DBS stimulation parameters are set too high, the patient behaves more impulsively, a sign of excessive self-confidence [3]. Drawing on the active inference framework [4], we hypothesise that DBS-induced changes in precision expectations may provide a neurocognitive explanation of the rapid change in self-confidence that our patients report.

What is Self-Confidence?

People are self-confident when they trust their abilities and surroundings. Self-confidence allows them to be open to the various action possibilities that are relevant to them [2]. We will therefore understand self-confidence in terms of the person's experience of their power to act in the world. Self-confidence can be given a neurocognitive description in terms of 'active inference', the process of action selection that minimises the 'surprise' expected as a consequence of acting [4]. Agents expect their future sensory states to match those they value or desire, and are surprised when such expectations are violated. In active inference terms, an agent can be said to act with self-confidence when they trust their actions will lead to the outcomes they expect, and thereby minimise surprise [5].

Self-confidence is reduced in OCD. The person's power to act in the world is severely diminished by their illness. OCD patients anticipate dangers such as contamination, and threats such as causing harm to others, or performing actions they find morally repugnant [6]. The reduced self-confidence our patients report is the result of their actions being driven by their anticipation of threat and danger. We suggest that DBS increases self-confidence by allowing the patient to again be open to other possibilities for action and not only those that relate to their fear and anxiety.

The Active Inference Account of OCD

Neil Levy has recently suggested OCD may be due to an imbalance in the relative influence of top-down predictions and incoming sensory information [7]. In OCD, the agent anticipates threats such as contamination. Expectations of this type are assigned high precision. 'Precision' refers to the confidence or certainty an agent has in the predictions of an action policy (see [5] and Box 1). The person with OCD acts on action policies driven by their anxiety and fear. They pay no attention to conflicting sensory information, instead actively sampling the world in search of evidence confirming their anxiety-fuelled expectations. If the patients expect more dangers and they assign high precision to such expectations, they will as a result perceive more dangers even when there is no danger present in the environment.

In work on active inference, neurotransmitters such as dopamine are hypothesized to weigh the precision of action policies, ensuring agents act on policies which they have high confidence will minimise future surprise [5]. The ventral striatum is well known for playing a role in dopaminergic function [8]. Thus there is good reason to think the ventral striatum, in communication with a wide range of other areas, plays a role in weighing the precision of action policies [5]. We previously found that vALIC-DBS reduces excessive functional connectivity between the ventral striatum and medial prefrontal cortex, which critically predicted decreases in OCD symptoms [9]. Finding the optimal level of DBS in the ventral striatum normalises communication between these brain areas. Recent work in healthy individuals suggests that the ventral striatum and ventromedial prefrontal cortex track choice-dependent and choice-independent subjective confidence, respectively [10]. This finding agrees with our hypothesis that the ventral striatum plays a key role in setting the precision on action policies.

We hypothesise that people with OCD weigh the precision of their action policies,

Box 1. Active Inference in an Agent-Environment System

Active inference is the process of selecting actions with sensory consequences that minimise long-term surprise [4,5]. 'Surprise' is quantified as prediction-error, the mismatch between top-down predictions of action policies and current sensory inputs. In earlier work we have argued for an interpretation of active inference in terms of the self-organising dynamics of a whole agent-environment system [11]. Prediction errors map onto relevant affordances: the possibilities for action the environment offers to agents. Precision expectations, we have suggested, determine the degree of influence of multiple relevant affordances on an agent's behaviour by weighing the salience of prediction errors. Thus active inference, we have argued, does not just happen in the brain but in the skilled engagement of the agent with a field of relevant affordances (Figure I).

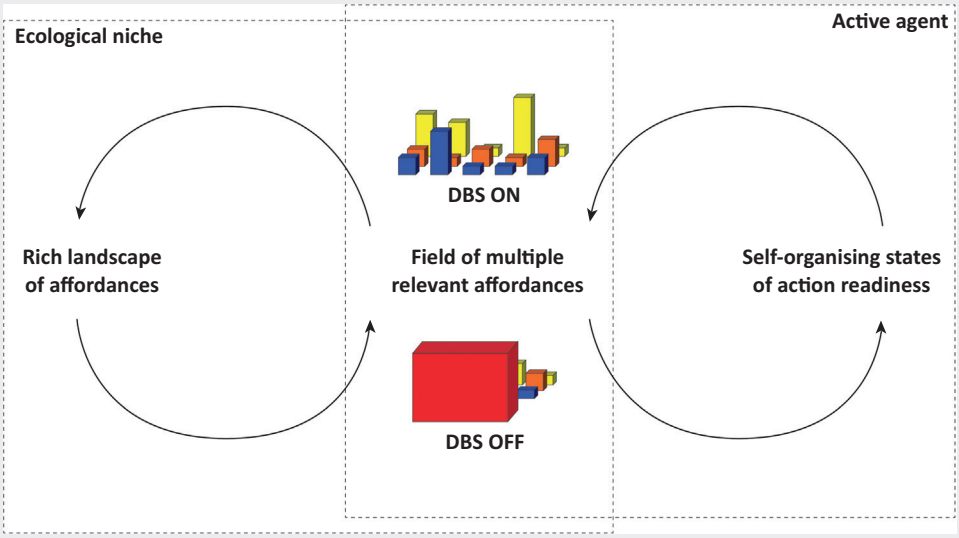

Figure I. The Impact of Deep Brain Stimulation (DBS) on Active Inference in the Agent-Environment System of People with Obsessive Compulsive Disorder (OCD)[a]. The coloured bars in the centre of the figure represent the field of relevant affordances with and without DBS. The field of multiple relevant affordances emerges out of the agent's dynamical coupling to the environment (ecological niche), understood by us as a landscape of affordances, which in turn changes the affordances available to act on. The arrows from the field of relevant affordances to the active agent illustrate the person's states of action readiness that self-organise in relation to the field of relevant affordances. The height and width of the bars in the central panel correspond to the precision or salience assigned to a relevant affordance belonging to the field. When a person with OCD and DBS OFF encounters something surprising (e.g., dirt on the floor of their otherwise spotless car) this elicits a prediction error that is given high precision. By weighing this prediction error as precise, action policies that reduce prediction error dominate (e.g., cleaning the car). DBS ON restores context-sensitive updating of precision expectations, thereby normalising the structure of their field of relevant affordances. It thus increases the person's action openness to and readiness for the many other action possibilities that also matter to them. The person is able to better anticipate what is relevant to them and thus experiences more self-confidence. [a]Based on [2] and [11].

in part, based on their fearful and anxious mode of relating to the world. This has the consequence that their anxious anticipations are in the driving seat when it comes to selecting the action possibilities that drive their behaviour (Box 1). The effect of DBS is to restore the context-sensitive weighing of precision expectations. This allows the person to better anticipate what is relevant to them, and thus to once again be open to the many action possibilities of significance to them. It is the recovery of their readiness for and grip on the world that accounts for their increased self-confidence (see Figure I in Box 1).

Concluding Remarks and Future Directions

DBS may prove an effective treatment for OCD patients because it allows the patient to once again be open to the many possible actions the world offers, and thereby increases their self-confidence. The subsequent improvements in OCD symptoms may be contingent on their regaining the power to act in the world. To test our hypothesis, future studies are needed that examine the effect of vALIC-DBS on precision expectations using behavioural tasks. These should also examine the underlying neural changes, which likely include changes in communication between the ventral striatum and a wider network of connected regions, including the ventromedial prefrontal cortex.

More research is also needed to establish whether the effects on self-confidence can only be achieved through DBS of the vALIC. Stimulating the subthalamic nucleus (STN) has been shown to reduce compulsivity, but is less anxiolytic than vALIC-DBS [12]. How does stimulation of STN, compared with vALIC, impact the patients' openness to action

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possibilities and self-confidence? Our prediction is that as long as anxiety-related anticipation is not reduced, the patient will remain at least partly closed off from the many possibilities they care about and their self-confidence will remain relatively low.

DBS changes the structure of a patient's field of inviting affordances [2]. This is, we suggest, why the patient experiences more self-confidence. As long as precision is high for anxious anticipations, this will result in the person focusing only on the dominant affordance(s) relating to their anxious state of anticipation. When anxiety reduces, the person is once again open to dealing with the many other action possibilities the environment makes available. The result of this openness and readiness for the world is increased self-confidence.

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Forum

A Novel Framework for Unconscious Processing

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Understanding the distinction between conscious and unconscious cognition remains a priority in psychology and neuroscience. A comprehensive neurocognitive account of conscious awareness will not be possible without a sound framework to isolate and understand unconscious information processing. Here, we provide a brain-based framework that allows the identification of unconscious processes, even with null effects on behaviour.

Prior research has implicitly assumed that demonstrations of unconscious information processing require a behavioural effect triggered by unconscious stimulation. Fundamental challenges, however, remain to isolate unconscious information processing from behavioural tests. Here, we first review these challenges. Then, we propose a novel framework that leverages recent advances in neuroimaging technology and computational models to isolate unconscious information processing from brain activity patterns. In this framework, behavioural effects from unconscious stimuli are dispensable for demonstrations of unconscious representations. Our framework can be used to predict whether or not unconscious stimuli may influence behaviour.

Behavioural Tests of Unconscious Processing

Over the past decade or so, there has been a palpable shift towards the use of subjective reports to identify states of visual unawareness [1]. Trials in which observers report no awareness of a stimulus are used to infer the properties of unconscious processing mechanisms across multiple cognitive domains, including visual perception [2], learning, and memory [3].

Relying on subjective measures of awareness to understand unconscious information processing remains the subject of ongoing strong criticism [4]. One major concern is that weak, but above-chance, sensitivity may involve conscious knowledge of behaviour even when observers report no awareness of the information. Another is that subjective reports of (un) awareness may not exhaustively reveal all relevant knowledge (i.e., observers may not report knowledge held with very low confidence).