Autistic Cognition: Charting Routes to Anxiety

Eloise Stark[1,2]*, James Stacey[2], Will Mandy[3], Morten L. Kringelbach[1,4], and Francesca Happé[5]

[1] Department of Psychiatry, University of Oxford, Oxford, UK

[2] Oxford Health NHS Foundation Trust, Warneford Hospital, Oxford, UK

[3] Research Department of Clinical, Educational and Health Psychology, University College London, 1-19 Torrington Place, London, UK

[4] Center for Music in the Brain, Department of Clinical Medicine, Aarhus University, Denmark

[5] Social, Genetic and Developmental Psychiatry Centre, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, UK

* Correspondence: eloise.stark@psych.ox.ac.uk (E. Stark).

Keywords: autism, cognition, anxiety, predictive processing, intolerance of uncertainty, black and white thinking.

Abstract

Autism Spectrum Conditions are typified by a divergence in cognitive style from that of the non-autistic population. Cognitive differences in autism may underlie significant strengths, but also increase vulnerability to psychopathology such as anxiety, which is a major problem for a lot of autistic people. Many autistic people do not respond to typical psychotherapeutic interventions, suggesting that autism-specific models and interventions are needed. We advance a theoretical model explaining how three constructs attenuated predictions, intolerance of uncertainty, and “black and white thinking”, may interact to lead to anxiety in autism. We hope to start a dialogue surrounding how we can best address specific autistic cognitive differences that may lead to distress, via the development of appropriate models, measurements, and psychotherapeutic interventions.

Beyond Behaviour: Exploring Autistic Cognition

Human cognition is often biased, ranging from judgements in the moment, to estimations of future outcomes. Individuals with autism are not exempt from cognitive biases, and mounting evidence suggests that the autistic brain may be predisposed to several autism-specific differences in particular. There is no suggestion here that these differences are inherently disadvantageous, and for this reason, we primarily use the term differences instead of the commonly used term biases.

Autism is a relatively common neurodevelopmental condition, which is diagnosed primarily based upon behavioural characteristics [1]. However, how autistic people think is also notably different, and understanding these differences is paramount to understanding and supporting autistic people.

Autism is characterised by both challenges and strengths. Some of the strengths include a tendency to develop a passion for specific interests that “lie on a continuum with the focused interests of scientists, college professors…” [2], great attention to detail [3], the existence of extraordinary talent in art, music, maths, calendar calculation or memory [4], and a strong sense of justice [5].

Some of the key challenges for autistic individuals include hyper- or hypo-reactivity to sensory stimuli, such as an aversion to bright lights or loud sounds, or fascination with certain textures or objects, social-communicative and social interaction differences across multiple contexts, and an insistence on and preference for sameness and predictability [1].

Why study cognitive differences in autism?

Depression, anxiety, and phobias are all believed to involve ‘distortions’ to cognitions in neurotypical individuals [6-8] and huge progress has been made in developing psychotherapeutic techniques to treat such conditions by understanding the cognitive differences involved. However, we know far less about how specific cognitive differences may operate to cause and maintain these conditions in autistic individuals. Some cognitive behavioural treatments may even be harmful for autistic people if not adapted to their specific cognitions [9]. Autistic people and their families have highlighted that their top priority for research is to know which interventions, and appropriate adaptations, improve mental health for autistic people [10]. Understanding autistic cognitive differences is thus key for understanding and treating the psychological challenges that autistic people face.

It should be made clear that alongside exploring individual cognitive factors and their mechanistic relations to autistic psychological challenges, there are environmental and systemic factors beyond the control of the individual that may also contribute heavily to autistic distress. These include the fact that the physical, sensory and social environments are often not adequately adapted for autistic individuals, and that autistic individuals may experience high rates of trauma, stigma, and victimisation [11-13] which of course may lead to prolonged distress. Any impetus for the individual to change their cognitions or behaviour must therefore always be situated within an understanding of such societal factors.

The most common mental health challenge for autistic individuals is anxiety [14-16], occurring in an estimated 50% of children [17] and 42% of adults across their lifetime [15]. Anxiety in autistic individuals does not always present as it does in non-autistic individuals [18], and may be related to fear of loud sounds, for example, or extreme anxiety responses to inanimate objects [19, 20], perhaps related to atypical sensory experiences in autistic individuals [18]. Many studies implicate excessive worry in autism regarding change, and excessive rigidity about things such as foods, rituals, and clothing [18, 19, 21-23]. The key to understanding different presentations of anxiety in autism may lie in understanding autism-specific cognitive differences. There may be important differences in neurobiological, emotional and cognitive responses to stressors for autistic people, which warrant tailored anxiety models, assessments and interventions [24].

Herein we therefore explore three specific processes associated with autism and of potential relevance for anxiety: differences in **predictive processing** [25] (see **Glossary**), **intolerance of uncertainty** [26], and what is commonly referred to as **"black and white" thinking** [27]. While predictive processing is arguably a biological mechanism, intolerance of uncertainty and black and white thinking are psychological phenomena rooted in conscious and unconscious cognitive processing. We therefore explore predictive processing first, as an antecedent and underlying process important for understanding cognitive differences and their relation to anxiety in autism.

Predictive processing in autism: How does it differ?

Predictive processing (see **Box 1**) is a complex biological mechanism, which aims to develop an accurate predictive model of the environment through recursive optimisation of internal models. Sometimes, predictive processing may introduce bias into our perceptions and influence subsequent cognition. For example, we can use language or semantics to prime people to see specific items more easily, but miss others, such as in bistable perception (think of the rabbit-duck illusion). We therefore start with an exploration of predictive processing differences in autism in order to ascertain how this model operates and whether this may affect subsequent psychological biases. Evidence exploring top-down predictions in autism has sometimes indicated attenuated predictive processing, largely depending on the domain of information processing, such as auditory, linguistic or social predictions.

In the auditory domain, evidence for reduced or aberrant top-down predictions of auditory input is strong and consistent. One study found suboptimal integration of sensory evidence and prior perceptual knowledge in an auditory localization task in autistic adults [28]. There are indications that autistic individuals may be unable to anticipate the auditory sensory consequences of their own motor actions, demonstrating alterations in sensory attenuation of self-initiated sounds [29]. Furthermore, one electroencephalogram study demonstrated that autistic people appear to be less flexible in modulating their local predictions in an auditory task (reflected in lower mismatch negativity), supporting abnormal predictive coding accounts of autism [30]. Autistic traits have also been related to atypical precision-weighted integration of top-down and bottom-up neural signals using a hierarchical frequency tagging paradigm during EEG [31].

There is also evidence of reduced predictive processing in autism related to social situations. For example, during conversation, we need to predict when the other person will speak so that we can take turns and not talk over each other. Although some more basic aspects of action processing, such as biological motion, have been found to be unaffected in autism [32], more complex tasks do appear to lead to relative impairments of action prediction [33, 34]. For instance, the ability to successfully predict the action sequences of two individuals has been found to have an inverse relationship with increasing autistic traits [34]. One study reports that autistic perceivers required more time to encode the goal of the action, indicating longer processing time to use prior information [35].

Additional evidence in the social domain for abnormal predictive processing comes from two further studies. In one study measuring the prediction of trust and deception of a hypothetical person, autistic children did not show a performance gain comparable to non-autistic children when social information relating to the hypothetical person's trustworthiness was offered to them, but did show a comparable performance gain for helpful non-social information [36]. In the other study, attenuated use of priors in the social domain, assessed by asking participants to infer the intention of actors manipulating objects, was found to be related to clinical levels of social interaction impairment [37]. An atypical balance between top-down priors and bottom-up sensory evidence may provide an explanation for autistic challenges in inferring other people's mental states, by yielding significant deviations from normative Bayesian inference.

Challenging the notion that predictive mechanisms are pervasively different in autism, in a visual task requiring children to anticipate changes in dynamic objects, such as the time that an occluded car would reach the end of a track, no differences were found between autistic and non-autistic children [38]. The authors suggest that prediction abilities should be considered as a taxonomy of abilities, and that difficulties with prediction may be linked to factors such as sensory modality, the complexity of tasks or strength of predictive associations, such as tasks involving complex social predictions [38].

Similarly, the available evidence suggests that autistic individuals do not necessarily show attenuated predictions when processing linguistic constructs. During the prediction of sentences within an audiobook script, autistic listeners did not show differences in neural activity, measured by time-sensitive magnetoencephalography recordings, compared to non-autistic listeners [39]. Similarly, autistic 5-year-olds showed age-appropriate eye movements denoting accurate prediction of spoken sentence content [40].

There are two autistic phenomena which could be explained by predictive processing differences. For example, it has been proposed that the autistic preference for "sameness" may arise from the anxiety caused by a world in which unpredictability is elevated [25]. Reduced predictability of others and the environment may lead autistic individuals to strive for sameness as a way of ensuring maximum predictability. An insistence on sameness therefore goes hand in hand with the concept of intolerance of uncertainty.

Similarly, sensory hyper-sensitivity is another autistic phenomenon which could be explained via predictive processing accounts. Reduced habituation to sensory stimuli, for example, repeated sounds (a clock ticking) or smells (strong perfume), is theorised to result from the autistic individual not predicting the continuation of the stimulus. With the diverse and chaotic sensory environment of the modern world, this may therefore result in an experience of sensory overload [41] or, where the sensation is perceived as pleasurable, in sensory fascinations and sensory-seeking behaviours. The onslaught of seemingly novel perceptual information, and a lack of sensory filtering in autism [42] may subsequently lead to a greater weighting of bottom-up sensory information, thus perpetuating the cycle.

In summary, the evidence strongly suggests that autistic individuals do show attenuated predictive processing, but that there is perhaps a taxonomy of predictive abilities and not all of these are reduced.

Intolerance of uncertainty and anxiety in autism

Dealing with uncertainty or ambiguity is often difficult for autistic people, commonly resulting in anxiety [43]. This construct has been called “intolerance of uncertainty” (see **Box 2**) and was initially advanced under the study of generalised anxiety disorder [44]. Several studies have confirmed elevated levels of intolerance of uncertainty in autistic individuals compared to those without autism [26, 43, 45-47].

People need to make multiple decisions a day based upon some degree of uncertainty. There are different sorts of decisions, however, with some made under risk (with known probabilities for different choices), and others made under ambiguity (with unknown probabilities) [48]. It is these latter decisions, made under uncertainty, which are seemingly the most challenging for autistic people.

Intolerance of uncertainty has been proposed to comprise two factors: 1) a desire for predictability and an active engagement in seeking certainty, and 2) uncertainty paralysis, or a feeling of being cognitively or behaviourally ‘stuck’ in situations of uncertainty [49]. This is an interesting abstraction as it relates the two components to different cognitive elements and sees uncertainty paralysis as occurring secondary to a desire to predictability.

A desire for predictability can be framed in terms of motivational salience, which is a cognitive process that motivates or drives an individual’s behaviour to approach or avoid a particular stimulus. An active engagement in seeking certainty, relates to behavioural attempts to seek sufficient information to increase predictability. Both elements rely upon predictive processing of a future outcome or event. In the context of Intolerance of uncertainty, an individual would have a high motivational salience for high precision in predictive processes. Intolerance of uncertainty is therefore fundamentally related to predictive processing. Attempts to seek sufficient information may also lead an individual to take longer to make decisions, perhaps underlying some executive function difficulties seen in autism [50]. Uncertainty paralysis may be in part a reflection of executive challenges related to decision-making in situations of uncertainty, and may also be intrinsically linked to anxiety via the 'freeze' response [51]. Attenuated predictive processing in autism may thus, understandably, lead to a strong desire for, and attempts to establish, certainty, and the subsequent paralysis or freeze response when this is not possible.

Interestingly, attempts to alleviate uncertainty paralysis or regulate anxiety may relate to common autistic behaviours. Redirection of attention to strongly held interests, sensory-seeking behaviours and motor stereotypies that provide a predictable response, may all be used to regulate the effects of Intolerance of uncertainty. One study reported positive correlations between intolerance of uncertainty, anxiety, repetitive behaviour and sensory sensitivities in autistic adults, while Intolerance of uncertainty was a significant mediator between sensory sensitivities and anxiety [52]. This supports the central role of intolerance of uncertainty in the interrelationships between anxiety and autism traits in adults, complementing other studies that found intolerance of uncertainty as a significant mediator between autistic traits and anxiety in children and younger adults [53]. There already exists an elegant evidence-based model linking Intolerance of uncertainty and anxiety in autism, as well as atypical sensory function and alexithymia [54].

Black and White Thinking

> For those of us who are on the spectrum, almost everything is black or white.
>
> \- Greta Thunberg

Black and white thinking is binary, with no 'grey' in-between two polarised opinions. It can be helpful to think of judgements in terms of "fuzzy logic," which is an approach first applied to computing based on "degrees of truth" rather than the 1 or 0 Boolean logic upon which the computer is based. This approach was conceived by Zadeh in the 1960s [55], as he attempted to enable computer understanding of natural language, which is nigh impossible to translate in absolute terms of 0 or 1. Cognition typically follows a fuzzy logic too – something can be 0 or 1 in extreme cases of truth (black or white), but many states of truth are grey or an intermediary between 0 and 1.

In a survey of therapists with experience of working with autistic individuals, the most frequently reported barrier to the therapeutic process was said to be black and white thinking, with 40% of therapists noting this [27]. The authors suggest that such black and white thinking may lead to frustration on the part of both the client and the therapist, if techniques targeting cognitive change are inaccessible, potentially leading to less favourable therapeutic outcomes. In keeping with this, a study of people with anorexia undergoing **Cognitive Remediation Therapy** (which has the goal of increasing cognitive flexibility) found that individuals with high autistic traits did not improve on their outcome measures [56]. Individuals with a cognitive style characterised by 'rigidity' or a lack of flexibility may therefore require therapeutic adaptations to benefit from interventions.

Furthermore, a black-and-white thinking style has been speculated to increase suicidality by increasing the likelihood of an autistic individual becoming stuck in depressogenic and distressing thought patterns [57]. In eating disorders, rigid thinking is often exacerbated in autistic individuals and may contribute to eating disorder pathology [58]. It may also underlie literal thinking and incomprehension of metaphor if the individual perceives the truth of language use to be absolute or concrete, rather than ambiguous or conceptual.

Given the lack of experimental evidence concerning black and white thinking in autism, there has understandably been no corresponding research exploring its relation to anxiety. However, we may draw interesting insights from aligning black and white thinking with the concept of cognitive rigidity or inflexibility, a core characteristic of autism according to the DSM-5 [1]. Within the "autonomic flexibility-neurovisceral integration model of anxiety", it is argued that anxiety is inherently a systemic rigidity grounded in poor inhibition [59]. For example, anxious individuals may struggle to inhibit processes such as worry, thus appearing very rigid in their cognitive patterns. Cognitive rigidity has been associated as a key factor in anxiety disorders in non-autistic individuals, including obsessive compulsive disorder [60] and social anxiety [61].

Interestingly, cognitive rigidity has also been associated with internalising problems (e.g., anxiety) in autistic children, directly mediated by Intolerance of uncertainty[62]. However, cognitive rigidity may represent a larger range of cognitions (e.g., need for sameness) and associated behaviours (e.g., restricted and repetitive behaviours and interests; RRBIs) so cannot be directly equated with black and white thinking.

In summary, there is almost no literature on black and white thinking in autism, despite it being an anecdotal mainstay related to autistic cognition. What little evidence there is suggests that it is a presenting cognitive difference in at least some autistic individuals.

How do these cognitive differences interact in autism?

We herein propose a model for the interactions between attenuated top-down predictions, intolerance of uncertainty, and black and white thinking (see **Figure 1**). Experimental work incorporating behavioural measures and self-report questionnaires will be necessary to tease apart the relationships of these variables in autistic children, young people and adults, but we hope that the suggestions here will encourage discussion and future exploratory endeavours.

[Insert Figure 1 here]

There is strong evidence linking autism and attenuated predictive processing in some, but not all, domains, particularly those involving social and auditory processing. There may also be an interactive relationship between predictive processing and anxiety in autism. Anxiety has been associated with heightened prediction error signals, otherwise explained as augmented detection of the difference between the observed and expected body state [63]. In one model [63] anxiety may reflect a heightened interoceptive prediction signal. If, as we seem to find, autism represents a particular state of attenuated predictive processing, these error signals may be even larger. As shown in **Figure 1**, we represent this relationship between anxiety and attenuated top-down predictions as bi-directional.

No studies to date have studied both intolerance of uncertainty and predictive processing together in autism. Attenuated predictive processing has the consequence of making the environment, other individuals, and sensory perceptions more surprising and novel. The subjective feeling of being cognitively or behaviourally 'stuck' in situations of uncertainty [49] may directly result from the lack of precision in predictions for incoming events and stimuli and the constant anticipation of surprise, thus appearing inseparable from the predictive process. The other element of intolerance of uncertainty is postulated to be a desire for predictability, which may directly arise from the high unpredictability of many situations and lower precision of top-down predictions, yet seems temporally and mechanistically different, arising more as a response to the attenuation of predictions, rather than as a direct or integral element of the predictive process.

One possible link between intolerance of uncertainty and black and white thinking in autism is that to circumvent the discomfort of uncertainty, and not end up feeling 'stuck', autistic individuals may tend to attribute a binary outcome to uncertain states of truth, and thereby end up at a 'black or white' outcome that feels certain and thus reduces their anxiety. Black and white thinking may therefore be a safety behaviour, conscious or not, employed by autistic individuals in order to reduce uncertainty and associated anxiety in the short term. However, in the long term, the individual who relies upon binary outcomes in order to feel certain may never learn that uncertain situations do not end in catastrophe. By this logic, anxiety would also indirectly reinforce black and white thinking. This proposition has parallels with the similar suggestion that restricted and repetitive behaviours represent a strategic attempt to impose predictability in an uncertain world [64].

There are several testable hypotheses following on from this theoretical proposition: 1) Uncertain judgements of the state of truth would prompt anxiety, which would prompt a strategic binary response; 2) The safety behaviour of thinking in absolutes would typically apply only to situations of uncertainty; 3) Certain but intermediary or 'grey' states of truth would not induce black and white or binary/dichotomous thinking because the certainty and predictability would reduce anxiety; 4) Anxiety and intolerance of uncertainty would interact, potentially leading to a vicious cycle; and 5) There would be a bidirectional relationship between the level of anxiety and degree of black and white thinking. A further prediction may be that anxiety reduces the degree of certainty in predictions, further attenuating predictive processing. This prediction advocates for studies where anxiety is modulated and certainty in predictions measured concurrently.

Black and white thinking, intolerance of uncertainty and predictive processing could be similar or parallel constructs at different levels of explanation (for example, psychological and neural/computational). This could be tested empirically either by looking longitudinally for correlations between the constructs, or by sensitively exploring the temporal dynamics of the different processes to see where they fit along a processing hierarchy. Our model specifically hypothesises that black and white thinking emerges as a strategic means of gaining certainty, following the affective discomfort associated with intolerance of uncertainty and consequent cognitive-behavioural drive to gain predictability, and this too is empirically testable.

Concluding Remarks and Future Directions

There are several clinical implications arising from this body of research, although it is important to note that there exist vast individual differences within autistic individuals and so this model may not explain anxiety in all autistic individuals. Clinicians working with autistic individuals should be aware that predicting events, consequences and actions may sometimes (particularly in social contexts) be challenging for the individual. Uncertain or unpredictable contexts may induce anxiety and could possibly lead to dichotomous cognitions or behaviours. Assessment and treatment should take societal injustice and an individual's environment into consideration, to reduce external factors that may increase an individual's anxiety, as well as being mindful that high levels of environmental uncertainty may cause undue distress. Experimental studies have found, in neurotypical populations, that adaptive therapeutic techniques such as cognitive reappraisal may be optimally performed when the initial learning context and subsequent conditions for employing emotional regulation are predictable [65].

Autistic individuals undergoing cognitive therapies may benefit from quantitative measurements of intolerance of uncertainty and related constructs [66] as outcome measures, and perhaps targeted interventions focused upon intolerance of uncertainty directly, as high intolerance of uncertainty pre-therapy has been found to be linked to poorer post-therapy outcomes [67]. One UK research group has developed a parent-based group intervention to provide parents of autistic children with effective strategies for reducing their child's intolerance of uncertainty, which looks promising in terms of acceptability and feasibility [68, 69].

Autistic cognitive differences are not necessarily negative (see **Box 3**; see **Outstanding Questions**). Harnessing neurodiversity and exploring what gives autistic people joy is vital if we are to improve wellbeing among the autistic population. Ameliorating anxiety in autistic individuals should be a primary aim for both research and clinical practice. The model herein provides testable predictions and a strong impetus for studying cognitive routes to anxiety in autism in greater detail.

Box 1. Theories of Predictive Processing in Autism.

Several theories have attempted to explain core features of autism in terms of differences in predictive coding. Some researchers have proposed that autistic people see the world more accurately – as it really is – as a consequence of being less biased by their prior expectations [70]. The idea that they present is that prior beliefs, which generate top-down predictions, are somehow attenuated in autism, leading to an increased reliance on bottom-up sensory evidence. This would therefore suggest that to the autistic brain, incoming sensory input would seem more novel, and less familiar. There are several domains in which predictive processing does indeed seem attenuated in autism, including sensory predictions, and goal-directed action, as well as providing explanations for phenomena such as an insistence on sameness and sensory hyper- and hyposensitivity.

The specific nature of predictive processing in autism is under debate [71]. For instance, others [72] make the suggestion that in autism, there is not a failure of prediction specifically, but a failure to instantiate top-down predictions during perceptual synthesis because their assumed precision (confidence or reliability of the priors) is too low. This has thus been proposed to be a failure of metacognition instead of prediction, which is to say that the autistic brain may not accurately predict the precision of predictions or prior evidence (beliefs about beliefs) [72]. Of course, all perspectives are part of a larger discussion within neuroscience concerning the relative degree of top-down and bottom-up influences upon perception.

Box 2. Measuring Intolerance of Uncertainty.

Most studies to date have used questionnaire measures of intolerance of uncertainty, with a variety of questionnaires used, initially reflecting the construct as measured in Generalised Anxiety Disorder (GAD) [66], and latterly being adapted to reflect Intolerance of uncertainty in children and young people, such as the Intolerance of Uncertainty Scale: Child and Parent Versions [73]. Many studies have also explored the relationship of Intolerance of uncertainty with measures of anxiety in autism [45, 64, 67, 74].

The majority of studies exploring intolerance of uncertainty have used self-report measures, whereas a few with young samples have used caregiver report. A couple of studies have used experimental paradigms to measure intolerance of uncertainty: one used a potentiated startle paradigm with uncertain puffs of air to the neck [47] and another used pupillometry during an auditory habituation task [75]. Given the differences in methodology used to measure intolerance of uncertainty, it appears to be a consistent finding across measurements that the construct is strongly associated with autism and anxiety.

Box 3. Seeing the positives.

A “deficit model” of autism has largely dominated the scientific discourse surrounding autistic phenomenology [76]. Deficit models imply that restorative interventions are needed to align their cognition and behaviour with that of non-autistic people. Within this paper, we link specific cognitive differences in autism to the experience of anxiety, but also wish to consider whether such cognitive differences may represent significant strengths, either now or during evolution.

In a speech during April 2019, Greta Thunberg, 16-year-old climate activist and autistic schoolgirl, suggested that her autism and specifically her “black and white thinking” enabled her to see the reality of our climate emergency. Indeed, black and white thinking may underlie some of the perceived strengths of autism, such as a strong sense of justice [5], by forcing binary judgements and subsequent beliefs and positions about ethical situations. Some have presented the black and white thinking style as ‘realism’, reiterating the message that it isn’t always negative and can lead to important insights [77].

In autism, a different balance with predictive processing operations may have an adaptive purpose. If you use fewer priors from memory or have less precision for what you predict to perceive, you may be more likely to pick up on novel changes within the environment. Autistic individuals and their ability to see tiny changes in the environment, may have been optimally placed to perceive danger and warn others of such happenings.

Similarly, intolerance of uncertainty and associated anxiety may also reflect an adaptive advantage in situations of high threat. People with high Intolerance of uncertainty may be more likely to interpret ambiguous stimuli as threatening. This may now be unhelpful, leading to a preponderance of false alarms. However, in a hunter-gatherer society where life was precarious, the lower threshold for autonomic nervous system activation in the face of uncertainty may have been societally life-saving at the expense of individual somatic stress.

We can only conjecture on the evolutionary origins of cognitive differences in autism. It may be helpful for autistic individuals to cultivate self-compassion for their autistic cognitive style, knowing that evolutionarily, it may have helped our ancestors to survive and thrive. As Temple Grandin has speculated [78]: “human evolution was driven by… autistic people. The human race would still be sitting around in caves chattering to each other if it were not for them.”

Glossary

Black and White Thinking: A cognitive style where the individual thinks in absolutes, often referred to as “all or nothing” or “dichotomous” thinking. For example, a sports team or music band may be revered as ‘completely wonderful’ or believed to be ‘absolutely dreadful.

Intolerance of Uncertainty: There are several interlinked elements of intolerance of uncertainty, including a felt sense of discomfort or feeling “stuck”, cognitions characteristic of worry and a motivation for predictability, and behaviours such as avoidance of uncertain situations.

Predictive Processing: In predictive processing, our perceptions emerge from the “bottom-up” integration of sensory information from the environment with our “top-down” predictions for incoming sensory information based upon an internal representation of that information.

Cognitive Remediation Therapy: The primary aim of Cognitive Remediation Therapy (CRT) is to improve neuropsychological functioning, or the thinking process, rather than the content of thinking. CRT uses short cognitive exercises to explore cognitive processing and facilitate the exploration and use of alternative thinking styles. It has been used to improve cognitive processes such as flexibility, working memory, and planning.

Active inference: a theoretical perspective on brain function that defines action and perception as inferential processes, with the brain aiming to optimise its prediction of the surrounding environment using top-down influences upon sensory signals.

Perceptual inference: a theoretical perspective on brain function that defines action and perception as inferential processes, with the brain aiming to optimise its prediction of the surrounding environment by adjusting internal models to better fit the incoming sensory signals.

References

1. APA. (2013) Diagnostic and statistical manual of mental disorders (DSM-5®), American Psychiatric Association.

2. Jordan, C.J. and Caldwell-Harris, C.L. (2012) Understanding Differences in Neurotypical and Autism Spectrum Special Interests Through Internet Forums. Intellectual and Developmental Disabilities 50 (5), 391-402.

3. Shah, A. and Frith, U. (1983) An islet of ability in autistic children: A research note. Journal of Child Psychology and Psychiatry 24, 613-620.

4. Happé, F. and Frith, U., The beautiful otherness of the autistic mind, The Royal Society London, 2009.

5. Milner, V. et al. (2019) A Qualitative Exploration of the Female Experience of Autism Spectrum Disorder (ASD). Journal of Autism and Developmental Disorders 49 (6), 2389-2402.

6. Beck, A.T. (1975) Cognitive therapy and the emotional disorders, Intl Universities Press.

7. Beck, A.T. and Clark, D.A. (1997) An information processing model of anxiety: Automatic and strategic processes. Behaviour research and therapy 35 (1), 49-58.

8. Beck, A.T. et al. (2005) Anxiety disorders and phobias: A cognitive perspective, Basic Books.

9. Brede, J. et al. (2020) "For Me, the Anorexia is Just a Symptom, and the Cause is the Autism": Investigating Restrictive Eating Disorders in Autistic Women. J Autism Dev Disord 50 (12), 4280-4296.

10. Cusack, J. and Sterry, R. (2016) Your questions: shaping future autism research. London: Autistica.

11. Shtayermman, O. (2009) An exploratory study of the stigma associated with a diagnosis of Asperger's syndrome: The mental health impact on the adolescents and young adults diagnosed with a disability with a social nature. Journal of Human Behavior in the Social Environment 19 (3), 298-313.

12. Sreckovic, M.A. et al. (2014) Victimization of students with autism spectrum disorder: A review of prevalence and risk factors. Research in Autism Spectrum Disorders 8 (9), 1155-1172.

13. Rumball, F., Traumatic life events and the mechanisms of posttraumatic stress disorder development in adults with autism spectrum disorders, King's College London, 2018.

14. Mazefsky, C.A. et al. (2008) Overrepresentation of mood and anxiety disorders in adults with autism and their first-degree relatives: What does it mean? Autism research 1 (3), 193-197.

15. Hollocks, M.J. et al. (2019) Anxiety and depression in adults with autism spectrum disorder: a systematic review and meta-analysis. Psychological medicine 49 (4), 559-572.

16. Adams, D. et al. (2019) Anxiety in children with autism at school: A systematic review. Review Journal of Autism and Developmental Disorders, 1-15.

17. Simonoff, E. et al. (2008) Psychiatric disorders in children with autism spectrum disorders: prevalence, comorbidity, and associated factors in a population-derived sample. Journal of the American Academy of Child & Adolescent Psychiatry 47 (8), 921-929.

18. Kerns, C.M. et al. (2014) Traditional and atypical presentations of anxiety in youth with autism spectrum disorder. Journal of autism and developmental disorders 44 (11), 2851-2861.

19. Kanner, L. (1943) Autistic disturbance of affective contact. Nervous Child 2, 217-250.

20. Mayes, S.D. et al. (2013) Unusual fears in children with autism. Research in Autism Spectrum Disorders 7 (1), 151-158.

21. Leyfer, O.T. et al. (2006) Comorbid psychiatric disorders in children with autism: interview development and rates of disorders. Journal of autism and developmental disorders 36 (7), 849-861.

22. Ozsivadjian, A. et al. (2012) Parent and child perspectives on the nature of anxiety in children and young people with autism spectrum disorders: a focus group study. Autism 16 (2), 107-121.

23. Muris, P. et al. (1998) Comorbid anxiety symptoms in children with pervasive developmental disorders. Journal of anxiety disorders 12 (4), 387-393.

24. Rodgers, J. and Ofield, A. (2018) Understanding, recognising and treating co-occurring anxiety in autism. Current developmental disorders reports 5 (1), 58-64.

25. Sinha, P. et al. (2014) Autism as a disorder of prediction. Proceedings of the National Academy of Sciences 111 (42), 15220-15225.

26. Vasa, R.A. et al. (2018) Relationships between autism spectrum disorder and intolerance of uncertainty. Autism Research 11 (4), 636-644.

27. Cooper, K. et al. (2018) Adapting psychological therapies for autism. Research in Autism Spectrum Disorders 45, 43-50.

28. Skewes, J.C. and Gebauer, L. (2016) Brief report: suboptimal auditory localization in autism spectrum disorder: support for the bayesian account of sensory symptoms. Journal of autism and developmental disorders 46 (7), 2539-2547.

29. van Laarhoven, T. et al. (2019) Electrophysiological alterations in motor-auditory predictive coding in autism spectrum disorder. Autism Research 12 (4), 589-599.

30. Goris, J. et al. (2018) Sensory Prediction Errors Are Less Modulated by Global Context in Autism Spectrum Disorder. Biological Psychiatry: Cognitive Neuroscience and Neuroimaging 3 (8), 667-674.

31. Coll, M.-P. et al. (2020) Autistic traits are associated with atypical precision-weighted integration of top-down and bottom-up neural signals. Cognition 199, 104236.

32. Cusack, J.P. et al. (2015) Action perception is intact in autism spectrum disorder. Journal of Neuroscience 35 (5), 1849-1857.

33. Bolis, D. and Schilbach, L. (2018) Observing and participating in social interactions: action perception and action control across the autistic spectrum. Developmental cognitive neuroscience 29, 168-175.

34. Von Der Lühe, T. et al. (2016) Interpersonal predictive coding, not action perception, is impaired in autism. Philosophical Transactions of the Royal Society B: Biological Sciences 371 (1693), 20150373.

35. Ganglmayer, K. et al. (2019) Do children and adults with autism spectrum condition anticipate others' actions as goal-directed? A predictive coding perspective. Journal of autism and developmental disorders, 1-13.

36. Lu, H. et al. (2019) The Perceived Social Context Modulates Rule Learning in Autism. Journal of autism and developmental disorders 49 (11), 4698-4706.

37. Chambon, V. et al. (2017) Reduced sensitivity to social priors during action prediction in adults with autism spectrum disorders. Cognition 160, 17-26.

38. Tewolde, F.G. et al. (2018) Visual Motion Prediction and Verbal False Memory Performance in Autistic Children. Autism Research 11 (3), 509-518.

39. Brennan, J.R. et al. (2019) Predictive sentence comprehension during story-listening in autism spectrum disorder. Language, Cognition and Neuroscience 34 (4), 428-439.
40. Zhou, P. et al. (2019) Predictive Language Processing in Preschool Children with Autism Spectrum Disorder: An Eye-Tracking Study. Journal of Psycholinguistic Research 48 (2), 431-452.
41. Guiraud, J.A. et al. (2011) Differential habituation to repeated sounds in infants at high risk for autism. Neuroreport 22 (16), 845-849.
42. Lane, A.E. et al. (2010) Sensory processing subtypes in autism: Association with adaptive behavior. Journal of autism and developmental disorders 40 (1), 112-122.
43. Boulter, C. et al. (2014) Intolerance of uncertainty as a framework for understanding anxiety in children and adolescents with autism spectrum disorders. Journal of autism and developmental disorders 44 (6), 1391-1402.
44. Freeston, M.H. et al. (1994) Why do people worry? Personality and individual differences 17 (6), 791-802.
45. Hwang, Y.I. et al. (2020) Understanding anxiety in adults on the autism spectrum: An investigation of its relationship with intolerance of uncertainty, sensory sensitivities and repetitive behaviours. Autism 24 (2), 411-422.
46. Maisel, M.E. et al. (2016) Modeling the cognitive mechanisms linking autism symptoms and anxiety in adults. Journal of Abnormal Psychology 125 (5), 692.
47. Chamberlain, P.D. et al. (2013) A potentiated startle study of uncertainty and contextual anxiety in adolescents diagnosed with autism spectrum disorder. Molecular Autism 4 (1).
48. Knight, F.H. (2012) Risk, uncertainty and profit, Courier Corporation.
49. Berenbaum, H. et al. (2008) Intolerance of uncertainty: Exploring its dimensionality and associations with need for cognitive closure, psychopathology, and personality. Journal of Anxiety Disorders 22 (1), 117-125.
50. Demetriou, E.A. et al. (2018) Autism spectrum disorders: a meta-analysis of executive function. Mol Psychiatry 23 (5), 1198-1204.
51. Birrell, J. et al. (2011) Toward a definition of intolerance of uncertainty: a review of factor analytical studies of the Intolerance of Uncertainty Scale. Clin Psychol Rev 31 (7), 1198-208.

52. Hwang Ye, I. et al. (2020) Understanding anxiety in adults on the autism spectrum: An investigation of its relationship with intolerance of uncertainty, sensory sensitivities and repetitive behaviours. Autism 24 (2), 411-422.
53. Jenkinson, R. et al. (2020) The relationship between intolerance of uncertainty and anxiety in autism: A systematic literature review and meta-analysis. Autism, 1362361320932437.
54. South, M. and Rodgers, J. (2017) Sensory, Emotional and Cognitive Contributions to Anxiety in Autism Spectrum Disorders. Front Hum Neurosci 11, 20.
55. Zadeh, L.A. (1965) Fuzzy Sets. Information and Control 8, 338-353.
56. Tchanturia, K. et al. (2016) How anorexia nervosa patients with high and low autistic traits respond to group Cognitive Remediation Therapy. BMC psychiatry 16 (1), 334.
57. Storch, E.A. et al. (2013) The phenomenology and clinical correlates of suicidal thoughts and behaviors in youth with autism spectrum disorders. Journal of autism and developmental disorders 43 (10), 2450-2459.
58. Kinnaird, E. et al. (2019) Eating as an autistic adult: An exploratory qualitative study. PloS one 14 (8).
59. Friedman, B.H. and Thayer, J.F. (1998) Autonomic balance revisited: panic anxiety and heart rate variability. Journal of psychosomatic research 44 (1), 133-151.
60. Meiran, N. et al. (2011) Cognitive rigidity in unipolar depression and obsessive compulsive disorder: examination of task switching, Stroop, working memory updating and post-conflict adaptation. Psychiatry Res 185 (1-2), 149-56.
61. Arlt, J. et al. (2016) Contributions of cognitive inflexibility to eating disorder and social anxiety symptoms. Eat Behav 21, 30-2.
62. Ozsivadjian, A. et al. (2020) Is cognitive inflexibility a missing link? The role of cognitive inflexibility, alexithymia and intolerance of uncertainty in externalising and internalising behaviours in young people with autism spectrum disorder. J Child Psychol Psychiatry.
63. Paulus, M.P. and Stein, M.B. (2006) An insular view of anxiety. Biological psychiatry 60 (4), 383-387.
64. Joyce, C. et al. (2017) Anxiety, intolerance of uncertainty and restricted and repetitive behaviour: Insights directly from young people with ASD. Journal of Autism and Developmental Disorders 47 (12), 3789-3802.

65. Imburgio, M.J. and MacNamara, A. (2019) Cognitive reappraisal in an unpredictable world: Prior context matters. International Journal of Psychophysiology 146, 173-179.

66. Buhr, K. and Dugas, M.J. (2002) The intolerance of uncertainty scale: Psychometric properties of the English version. Behaviour research and therapy 40 (8), 931-945.

67. Keefer, A. et al. (2017) Intolerance of Uncertainty Predicts Anxiety Outcomes Following CBT in Youth with ASD. Journal of Autism and Developmental Disorders 47 (12), 3949-3958.

68. Rodgers, J. et al. (2019) Coping with Uncertainty in Everyday Situations (CUES©) to address intolerance of uncertainty in autistic children: Study protocol for an intervention feasibility trial. Trials 20 (1).

69. Rodgers, J. et al. (2017) Towards a treatment for intolerance of uncertainty in young people with autism spectrum disorder: development of the coping with uncertainty in everyday situations (CUES©) programme. Journal of autism and developmental disorders 47 (12), 3959-3966.

70. Pellicano, E. and Burr, D. (2012) When the world becomes 'too real': a Bayesian explanation of autistic perception. Trends in cognitive sciences 16 (10), 504-510.

71. Palmer, C.J. et al. (2017) Bayesian approaches to autism: Towards volatility, action, and behavior. Psychological Bulletin 143 (5), 521-542.

72. Friston, K.J. et al. (2013) On hyperpriors and hypopriors: comment on Pellicano and Burr. Trends in cognitive sciences 17 (1), 1.

73. Boulter, C. et al. (2014) Intolerance of uncertainty as a framework for understanding anxiety in children and adolescents with autism spectrum disorders. J Autism Dev Disord 44 (6), 1391-402.

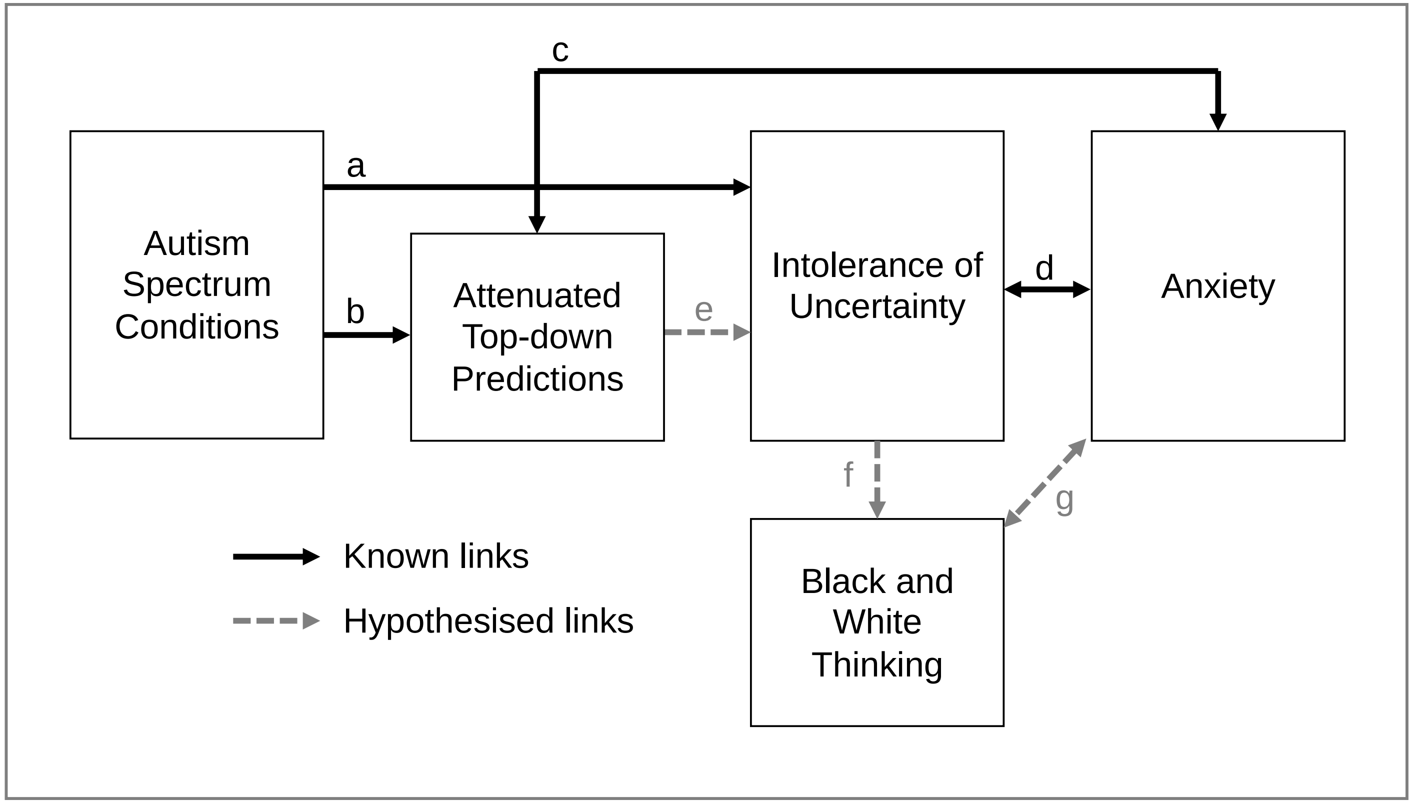
74. Glod, M. et al. (2019) Short report: Relationships between sensory processing, repetitive behaviors, anxiety, and intolerance of uncertainty in autism spectrum disorder and Williams syndrome. Autism Research 12 (5), 759-765.

75. Top, D.N., Jr. et al. (2018) Psychophysiological arousal and auditory sensitivity in a cross-clinical sample of autistic and non-autistic anxious adults. Frontiers in Psychiatry 9.

76. Robertson, S.M. (2009) Neurodiversity, quality of life, and autistic adults: Shifting research and professional focuses onto real-life challenges. Disability Studies Quarterly 30 (1).

77. Gaus, V.L. (2011) Living well on the spectrum: How to use your strengths to meet the challenges of Asperger syndrome/high-functioning autism, Guilford Press.
78. Deane-Drummond, C. and Fuentes, A. (2017) The Evolution of Human Wisdom.
79. Rowley, E. et al. (2012) The experience of friendship, victimization and bullying in children with an autism spectrum disorder: Associations with child characteristics and school placement. Research in Autism Spectrum Disorders 6 (3), 1126-1134.

Figure 1. A theoretical model of the interaction between three cognitive styles in autism and their causal role in anxiety. Alongside an awareness of environmental and systemic factors (e.g., trauma, stigma, prejudice) that undoubtedly increase anxiety, there are several hypothesised and evidence-based links within our model concerning the internal factors driving autistic anxiety: (a) intolerance of uncertainty has been robustly associated with autism, although given that predictive processing and Intolerance of uncertainty have never been studied in conjunction, we do not know if this is a direct link or potentially mediated by attenuated top-down predictions; (b) attenuated top-down predictions appear to be present in some, but not all, domains in autism; (c) If you make fewer or less precise predictions of incoming stimuli, this may directly lead to anxiety about the environment; (d) there are known links between intolerance of uncertainty and anxiety; (e) attenuated or less precise predictions would make the environment, and perhaps even one's own internal state, unpredictable and surprising, leading to greater intolerance of uncertainty; (f) intolerance of uncertainty may lead to strategic use of binary judgements and decisions to ensure certainty, which in turn could ameliorate the original anxiety associated with uncertainty (g); (g) the anxiety associated with intolerance of uncertainty may also prompt black and white thinking. If autistic individuals are at risk of anxiety-engendering experiences (due to experiences such as encountering stigma or victimization which are both sadly more prevalent in autistic individuals compared to non-autistic people [11, 79]) then anxiety may also feed into this model at a greater degree than for non-autistic individuals.


c
a
Autism Spectrum Conditions
b
Attenuated Top-down Predictions
e
Intolerance of Uncertainty
d
Anxiety
f
g
Black and White Thinking
Known links
Hypothesised links

689

Highlights

- Autism appears to be related to several cognitive differences, including attenuated predictive processing and intolerance of uncertainty. Preliminary evidence also suggests a “black and white” thinking style.
- In non-autistic people, anxiety is often causally related to cognitive biases, and the aforementioned cognitive differences all have strong links to anxiety in autistic people.
- We therefore propose a model which accounts for how these key cognitive differences are interrelated and lead to anxiety in autism specifically, as well as proposing testable hypotheses to guide possible future research.

Outstanding Questions

- How do autistic cognitive differences interact and impact or mediate other autistic features such as sensory hypersensitivity, sensory hyposensitivity, and what is known diagnostically as ‘repetitive and/or rigid behaviours’?
- What is the relationship between attenuated predictive processing and intolerance of uncertainty? Is attenuated predictive processing causal in generating IoU? This may be best answered using a longitudinal design or intervention studies, especially when determining the best treatment targets for anxiety.
- How do the full range of autistic cognitive styles (e.g., weak central coherence, insistence upon sameness, restricted and repetitive behaviours, etcetera) interact? Network analysis may be useful in comprehending a broader constellation of cognitive and behavioural autistic features in individuals and across the autistic population, and how autism-specific psychopathology may emerge across the lifespan.
- Is black and white thinking employed as an emotion regulation strategy in response to uncertainty anxiety solely in autism? Or is this a common response in those who have high IoU?
- What are the strengths of autistic cognitive differences? How can we harness such differences to promote autistic joy and enable autistic flourishing?