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# Uncertainty Processing in Autism

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## Definition

A summary of theory and research on the relevance of uncertainty processing to core symptoms of autism spectrum disorder.

## Historical Background

Autism spectrum disorder (ASD) is often associated with a difficulty in processing and a lack of preference for uncertainty in the environment. Since the first description of ASD by Leo Kanner, ASD has been associated with a preference for sameness and predictability. Kanner described this cluster of symptoms as "an anxiously obsessive desire for the maintenance of sameness" and explained that "changes of routine, of furniture arrangement, of a pattern, of the order in which every day acts are carried out, can drive him [a child with ASD] to despair" (Kanner 1944, pp. 215). Other early conceptualizations have suggested that individuals with ASD tend to have extremely negative reactions to unexpected events (Baron-Cohen 1989; Dawson and Lewy 1989; Hutt et al. 1964).

Since the first inclusion of autism in the *Diagnostic and Statistical Manual of Mental Disorders* (a classification system for all psychiatric disorders), the diagnostic criteria for autism have always included atypical responses to uncertainty as a core symptom. The *Diagnostic and Statistical Manual of Mental Disorders*, third Edition (DSM-III), the first version to include autism, describes "Bizarre responses to various aspects of the environment, e.g., resistance to change" as a symptom of infantile autism (APA 1980). The Revised DSM-III (DSM-III-R) includes the following symptoms of autistic disorder: "Marked distress over changes in trivial aspects of environment (for example, when a vase is moved from usual position)" and "Unreasonable insistence on following routines in precise detail (for example, insisting that exactly the same route always be followed when shopping)" (APA 1987). The DSM-IV describes "Apparently inflexible adherence to specific, nonfunctional routines or rituals" as a possible symptom of autistic disorder (APA 1994). Most recently, the DSM-5 includes the following as a symptom of ASD: "inflexible


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adherence to routines, or ritualized patterns of verbal or nonverbal behavior (e.g., extreme distress at small changes, difficulties with transitions, rigid thinking patterns, greeting rituals, need to take same route or eat the same food every day)" (APA 2013).

## Current Knowledge

### Relations Between Uncertainty Processing and Autism Symptoms and Features

Impairments in processing uncertainty, and impairments in the related construct of prediction, are increasingly being recognized as important features of ASD that are linked to core symptoms and co-occurring conditions associated with ASD. Previous research indicates that children with ASD prefer to engage in predictable or repetitive tasks (Boucher 1977) and demonstrate increased attention to and engagement with objects presented underpredictable versus unpredictable conditions (Ferrara and Hill 1980). Children with ASD also show an exaggerated response to changes in their environment (Kootz et al. 1982) and reduced exploration of novel or unfamiliar environments (Pierce and Courchesne 2001). Individuals with ASD also report that changes in their schedules or transitions are one of the primary sources of stress in their lives (Gillott and Standen 2007).

The two defining features of ASD, impaired processing of social and communicative information and restricted repetitive behaviors (APA 2013), both have relevance to uncertainty processing. First, a preference for sameness and aversion toward uncertainty would undoubtedly impact social functioning in individuals with ASD given the inherent unpredictable nature of social stimuli in the naturalistic environment. The complexity and dynamicity of human interactions make predicting social behavior extremely difficult, even for the most socially skilled individuals. Yet, for individuals with ASD, fundamental deficits in perspective-taking and social attention likely make social stimuli even more unpredictable. Thus, a preference for predictability in ASD, along with pervasive social deficits, may ultimately reduce motivation to attend to and interact with social stimuli in ASD.

In contrast to this pattern of reduced social motivation, individuals with ASD often have intense, specialized, and restricted interests referred to as *circumscribed interests* (APA 2013). These interests are more intense and less flexible than interests in typically developing (TD) children and frequently interfere with the development of social relationships and participation in functional activities (Klin et al. 2007; Turner-Brown et al. 2011). Interestingly, the most common circumscribed interests in ASD are predictable objects, events, or functions (e.g., machines, mechanical systems, vehicles, computers) (Baron-Cohen and Wheelwright 1999; Turner-Brown et al. 2011). Likewise, for decades it has also been recognized that some individuals with ASD have enhanced skills in certain domains. These so-called islets of abilities (Shah and Frith 1983) typically are in topics related to mathematics, calendar calculations, and visual search tasks (Pring 2005). Typically, what these domains have in common is that they are rule-based and predictable, thereby minimizing ambiguity and uncertainty. More recent evidence also indicates that an intolerance of uncertainty is associated with sensory sensitivity (Neil et al. 2016) and repetitive behaviors in ASD (Vasa et al. 2018).

Therefore, both areas of preserved abilities and impairments in ASD share an affinity for certainty and an aversion of uncertainty. For this reason, understanding uncertainty processing in ASD is likely of prime importance to gain insight into cognitive systems with etiologic relevance to the disorder.

More broadly, two recent theoretical models have suggested that a core deficit in ASD may be related to how individuals with ASD process uncertain events and develop predictions based on these events. The first model, proposed by Sinha et al. (2014), suggests that individuals with ASD have an impaired ability to understand predictive relationships in the environment. According to this model, an inability to effectively develop and test predictive hypotheses results in individuals with ASD living in a constantly unpredictable and uncertain environment. Insistence on sameness and avoidance of social interaction thus minimizes the impact of this deficit. A second theoretical model, developed by Van de Cruys et al. (2014), builds upon the first model by suggesting that impaired predictive coding in ASD is the result of an inability to learn from relevant predictive cues in a dynamic and uncertain environment. According to this model, individuals with ASD are overly attuned to uncertainty in the environment as they expect every situation to meet very precise predictions based on past events. Thus, they place too much weight on irrelevant violations of their expectations and predictive coding becomes shaped by environmental noise or random variability rather than relevant cues. The authors suggest that this effect is particularly robust in complex and dynamic situations such as social interactions. Accordingly, individuals with ASD may prefer to engage in repetitive and stereotyped behaviors with known contingencies, while avoiding the relative uncertainty of social interactions.

**Intolerance of Uncertainty and Anxiety in ASD**
Processing uncertainty in the environment is a critical component of learning, and the drive to resolve uncertainty has been proposed to be a principal motivating force for nearly all human behavior (Kagan 1972). The preference for predictability in ASD bears notable resemblance to a construct that has been primarily studied in the context of anxiety disorders referred to as "intolerance of uncertainty" (Rodgers et al. 2012). Individuals with intolerance of uncertainty find uncertain situations stressful and distressing, tend to interpret ambiguous information as threatening, and find it difficult to function in the face of uncertainty (Buhr and Dugas 2009). An intolerance of uncertainty is a characteristic of a range of anxiety disorders, including generalized anxiety disorder (Ladouceur et al. 2000b), obsessive-compulsive disorder (Tolin et al. 2003), and social anxiety disorder. Although the causal relationship between intolerance of uncertainty and anxiety warrants further research, it is clear that intolerance of uncertainty serves as a broad vulnerability factor for anxiety disorders (Carleton 2012). In addition, intolerance of uncertainty is a common intervention target in anxiety disorders, and treatment-related reductions in the intolerance of uncertainty are associated with reduced anxiety in individuals with anxiety disorders (Wilkinson et al. 2011).

As many as 50–75% of individuals with ASD meet criteria for an anxiety disorder (Mosner et al. 2019), and individuals with ASD often meet criteria for multiple anxiety disorders (Simonoff et al. 2008). A growing body of research is focused on understanding intolerance of uncertainty in autism and has consistently found elevated intolerance of uncertainty in children and adults with autism (Rodgers et al. 2017). There is evidence for strong positive correlations between anxiety and IU in ASD (Boulter et al. 2013; Chamberlain et al. 2013; Wigham et al. 2014) and evidence that intolerance of uncertainty mediates the relationship between anxiety and ASD, suggesting that intolerance of uncertainty may play a causal role in the development of anxiety in ASD (Boulter et al. 2013). However, it remains unclear the extent to which the aversion to uncertainty in ASD is characterized by beliefs that uncertainty necessarily results in negative outcomes as is the case in anxiety disorders (Koerner and Dugas 2006, 2008). Kerns et al. (2014) suggested that distress associated with uncertainty may be an important factor in the development of anxiety in ASD, highlighting that intolerance of uncertainty is an important mechanism contributing to the emergence of anxiety in ASD and an appropriate target for ASD intervention. Boulter et al. (2014) found that intolerance of uncertainty and anxiety were correlated in ASD and that intolerance of uncertainty mediates the ASD-anxiety association (in other words, intolerance of uncertainty may be a causal factor of anxiety in ASD). According to this model, insistence on sameness in ASD may serve as a maladaptive coping strategy aimed at reducing uncertainty and thus anxiety. Additionally, in a group of children with ASD receiving treatment for anxiety, high levels of pretreatment intolerance of uncertainty predicted poorer treatment response (Keefer et al. 2017). Further, in a study designed to validate a new self- and parent-report measure of anxiety in children with ASD using factor analysis, Rodgers et al. (2016) identified four anxiety factors in ASD, one of which was an uncertainty intolerance subscale.

The "insistence on sameness" symptom observed in most individuals with ASD shares many qualities with intolerance of uncertainty. This symptom domain includes repetitive thoughts and actions, behavioral rigidity, a reliance on routines, resistance to change, and obsessive adherence to rituals. Ritualistic behaviors and insistence on sameness in ASD may reflect behaviors that function to minimize uncertainty in the environment. Additionally, insistence on sameness behaviors in ASD may reflect, at least in part, processes to reduce anxiety in the face of intolerance of uncertainty. Anxiety disorders are characterized by active avoidance of high uncertainty situations to avoid accompanying negative emotions. Outside of the context of ASD, anxiety is modulated by predictability even if the uncertain outcomes do not have aversive consequence (Grupe and Nitschke 2013). Additionally, anxiety is a cause of ritualistic and repetitive behaviors, including benign leg-swinging in typically developing children (Soussignan and Koch 1985) and self-injurious stereotypies in animal model studies (Fox 1986). Across species, there is compelling evidence that ritualistic and repetitive behaviors that manifest under conditions of uncertainty or unpredictability are anxiolytic, serving to elicit calm under conditions of stress (Eilam et al. 2011). In this manner, insistence on sameness and associated ritualistic behaviors in the context of uncertainty may be adaptive responses to anxiety that is prompted by intolerance of uncertainty.

Indeed, anxiety symptoms and disorders are highly prevalent in ASD and anxiety is a common treatment target for individuals with ASD. Further, there appears to be a clear linkage between symptoms related to intolerance of uncertainty and anxiety in ASD. For example, in children with ASD with clinically significant anxiety, Rodgers et al. (2012) found a correlation between anxiety symptoms and insistence on sameness behaviors, but not other ASD symptoms. Similarly, Abramson et al. (2005) reported that children with increased insistence on sameness behaviors were more likely to have parents with anxiety symptoms.

### Emotional Regulation in ASD

Although the core features of ASD are in the domains of social communication and restricted and repetitive behaviors, ASD is characterized by broad impairments in affective expression and regulation, including tantrums, aggression, self-injury, anxiety, and irritability (Lecavalier 2006). Emotion regulation is a critical adaptive response that appears to be impaired in ASD, and these impairments may contribute to the increased rates of internalizing disorders in ASD given that such disorders are themselves characterized by impaired emotion regulation (White et al. 2009). Moreover, emotion regulation impairments in ASD are associated with the overall severity of all core ASD symptoms (Samson et al. 2014) and compromise the quality and quantity of early social interactions (White et al. 2014). Children with ASD frequently display decreased positive and increased negative emotional responses and poor recognition of emotions (Mazefsky et al. 2013). As already discussed, intolerance of uncertainty is a hallmark of anxiety disorders and is an associated feature of a number of ASD characteristics, including insistence on sameness and rigid adherence to routines. Additionally, given that, under conditions of uncertainty, ritualistic and repetitive behaviors may help to reduce anxiety, it may be the case that impaired emotion regulation may similarly be a risk factor for intolerance of uncertainty given impairments with emotion regulation that characterize ASD. In other words, impaired emotion regulation, combined with intolerance of uncertainty, may together potentiate anxiety symptoms that are so commonly observed in ASD. Indeed, there is some emerging evidence that intolerance of uncertainty is associated with emotional dysregulation in ASD, even when controlling for symptoms of anxiety (Vasa et al. 2018).

### Treatment Models for Uncertainty Processing

Outside of the context of ASD, most theories of psychosocial interventions for intolerance of uncertainty rely on cognitive strategies, including changing negative assumptions about uncertainty and seeking additional information. Based on a model in which uncertainty is a core deficit in anxiety disorders, Ladouceur and colleagues (2000a) designed a cognitive behavioral treatment for intolerance of uncertainty that addresses the four main components of intolerance of uncertainty. This treatment involved explaining the concept of intolerance of uncertainty; how to recognize, accept, and tolerate uncertainty in adaptive ways; the distinction between real and imagined negative outcomes; reevaluation of potentially positive beliefs about uncertainty; problem-solving training; and finally, exposure. A randomized controlled trial of adults with anxiety disorders found improvement in intolerance of uncertainty, anxiety symptoms, worry, and depressive symptoms that were maintained at 6- and 12-month posttreatment assessments, with 77% of the sample no longer meeting diagnostic criteria for anxiety disorders at both assessments (Ladouceur et al. 2000a). This treatment model suggests that intolerance of uncertainty and uncertainty processing are amenable to psychosocial intervention.

Although treatment methods that use cognitive strategies to cope with the intolerance of uncertainty in ASD are beginning to be evaluated, it is largely still unknown to what extent these approaches would be beneficial in the ASD population, and which patient characteristics might predict better treatment response. In general, individuals with ASD who have more skilled communication abilities are good candidates for psychosocial interventions (Wyman and Claro 2019), and future clinical trials should evaluate the efficacy of psychosocial interventions in targeting intolerance of uncertainty in ASD. In an initial study in this area, Keefer et al. (2017) examined whether intolerance of uncertainty affected outcomes following cognitive behavioral therapy for anxiety in children with ASD. They found that higher levels of pretreatment intolerance of uncertainty predicted higher anxiety before and after treatment, suggesting that targeting the intolerance of uncertainty may improve outcomes for therapy in youth with ASD. Finally, Rogers and colleagues (2018, 2017) recently developed "Coping with Uncertainty in Everyday Situations for Autism (CUES-A©)," a manualized treatment that targets intolerance of uncertainty in children with ASD. This intervention trains parents to help their children to manage intolerance of uncertainty. A recent initial validation study suggested that the intervention is feasible, acceptable, and valued by families. These results indicate that larger trials are warranted to evaluate the true effectiveness of this intervention.

## Behavioral Measures of Uncertainty Processing

Behavioral differences have also been found in terms of responding to uncertainty. Using a task referred to as the "beads task," which has been well-validated for measuring individual differences in responses to uncertainty (Broome et al. 2007; Ladouceur et al. 1997), adolescents with ASD tend to seek more information in an uncertain context before making a decision relative to controls (Brosnan et al. 2014). However, it may also be important to note that another study involving an adult sample found that the ASD group chose fewer beads (i.e., sought less information) than the control group (Jänsch and Hare 2014), suggesting that adults with ASD may use a "jumping to conclusions" approach (i.e., choosing only one or two beads before making a decision) as a coping strategy for avoiding the experience of uncertainty.

## Neurobiological Measures of Uncertainty Processing

There is also emerging evidence from neurobiological studies for atypical uncertainty processing in ASD. For instance, an event-related potential referred to as the "mismatch negativity (MMN)" indexes differences in the processing of unexpected events. Evidence for the MMN response in ASD is somewhat mixed. In individuals with ASD, the MMN response has been found to be reduced (Seri et al. 1999), increased (Ferri et al. 2003; Gomot et al. 2002), and, in some cases, statistically equivalent (Čeponienė et al. 2003; Kemner et al. 1995). In addition, studies of the P3a (an event-related potential response related to novelty processing) has consistently found attenuated P3a responses in children with ASD (Čeponienė et al. 2003; Courchesne et al. 1985, 1994; Dawson et al. 1988; Kemner et al. 1995;

Lincoln et al. 1993; Oades et al. 1988), indicating that children with ASD may be impaired in processing unexpected change.

Using a passive functional MRI task examining the processing of unexpected stimuli within a series of predictable stimuli, Gomot et al. (2006) found that children with ASD showed relatively reduced activation of the left anterior cingulate during the processing of unexpected stimuli. When this study was repeated as an active choice task, Gomot et al. (2008) found that children with ASD showed relatively increased activity in the right superior/middle and inferior frontal gyrus, right precentral gyrus, right postcentral gyrus, left inferior parietal lobule, and left middle frontal gyrus, as well as attenuated activation in the right caudate. Children with ASD were also faster at detecting the unexpected stimulus. When viewed in the light of the findings of Gomot et al. (2006), these results may suggest that children with ASD are able to process uncertain stimuli more effectively when their attention is directed toward it. However, it is important to note that Gomot et al. (2006) did not collect behavioral data and further research in this area is clearly needed in order to support these findings and rule out possible alternate explanations. In particular, attentional or multisensory processing deficits in ASD may explain this pattern of results. In addition, because response times were faster in the ASD group than the control group in this study, the hemodynamic response (as measured by fMRI) may have simply occurred earlier in the ASD group than the control group.

## Future Directions

Despite evidence for the high prevalence of intolerance of uncertainty and insistence on sameness in ASD (Lam and Aman 2007; Richler et al. 2007) and evidence that sameness and ritualistic behaviors in ASD significantly contribute to the stress of caregivers and adults with ASD (Boulter et al. 2014; Gabriels et al. 2005; Gillott and Standen 2007), the study of uncertainty processing in ASD is clearly an emerging field. Although intolerance of uncertainty has been studied extensively in individuals with anxiety disorders, the recognition of its relevance to core and associated ASD symptoms is a relatively new topic of inquiry. Although emerging data suggests that intolerance of uncertainty is related to insistence on sameness symptoms, anxiety, and emotion regulation impairments in ASD, research is needed to evaluate the extent to which the intolerance of uncertainty is associated with other ASD features. For example, intolerance of uncertainty in ASD has been found to be related to sensory sensitivities (Neil et al. 2016), and, together with anxiety, intolerance of uncertainty has been shown to mediate relations between sensory sensitivities and repetitive behaviors in children with ASD (Wigham et al. 2015). Additionally, Vasa et al. (2018) found that the severity of intolerance of uncertainty was related to the magnitude of social communication deficits, repetitive behaviors, and emotion dysregulation in children with ASD *while controlling for anxiety.* This important finding highlights the far-reaching impact of intolerance of uncertainty as it is related to core ASD symptoms. However, the extent to which interventions that target intolerance of uncertainty in ASD also impact the core symptoms of ASD remains to be evaluated.

A better understanding of the role of uncertainty processing in ASD may have important implications for identifying the active ingredients in effective behavioral interventions for ASD. Many empirically validated interventions for ASD are designed to increase predictability and minimize uncertainty, such as applied behavior analysis (ABA). The study of uncertainty processing in ASD may also inform the development of early intervention programs. If the uncertainty of social stimuli decreases their motivational salience, infants and toddlers at risk for ASD may choose to avoid or ignore social stimuli more and more over the course of development, ultimately resulting in greater social and communicative impairments later in life. Consequently, early intervention programs that increase the predictability and consistency of social stimuli may help to prevent children from following this aberrant developmental trajectory. Interventions for ASD may also incorporate a component that directly addresses the elevated levels of intolerance of uncertainty in this population, such as the intervention designed by Rodgers et al. (2017).

Given the transdiagnostic nature of uncertainty processing, it is likely that the lessons learned about cognitive mechanisms of intolerance of uncertainty in other psychiatric disorders, particularly anxiety disorders, may guide research into intolerance of uncertainty and its treatment in ASD. The evidence highlighting the success of psychosocial treatments in targeting intolerance of uncertainty in anxiety disorders (Ladouceur et al. 2000a) combined with the high rates of anxiety disorders in ASD (Leyfer et al. 2006), suggest that lessons learned from studying and treating intolerance of uncertainty in anxiety disorder may be a promising starting point to more fully investigate intolerance of uncertainty and ultimately develop treatments for intolerance of uncertainty in ASD.

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