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Review

Enhanced rationality in autism spectrum disorder

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Challenges in social cognition and communication are core characteristics of autism spectrum disorder (ASD), but in some domains, individuals with ASD may display typical abilities and even outperform their neurotypical counterparts. These enhanced abilities are notable in the domains of reasoning, judgment and decision-making, in which individuals with ASD often show 'enhanced rationality' by exhibiting more rational and bias-free decision-making than do neurotypical individuals. We review evidence for enhanced rationality in ASD, how it relates to theoretical frameworks of information processing in ASD, its implications for basic research about human irrationality, and what it may mean for the ASD community.

Highlights

Most research into autism spectrum disorder (ASD) focuses on difficulties and challenges, potentially overlooking intact and even enhanced abilities.

Empirical evidence strongly suggests that individuals with ASD display enhanced rationality: judgments that are more objective and decision-making that is less biased than that of neurotypical individuals.

Enhanced rationality may confer distinct strengths to individuals with ASD and may provide insights into the mechanism or 'irrationality' in neurotypical individuals.

Are humans inevitably irrational? Evidence from ASD

The seminal idea of **irrationality** (see Glossary) refers to the tendency of humans to process information in a biased manner, often leading to suboptimal reasoning and decision-making and a variety of **cognitive biases**. For example, people tend to favor information that confirms their existing beliefs and make decisions based on the way choices are presented rather than their objective content. This way of thought has been considered so fundamental that humans have been characterized as 'predictably irrational.' In the past several years, however, a growing literature suggests that individuals with autism spectrum disorder (ASD) display reduced susceptibility to cognitive biases and exhibit more rational and bias-free processing of information, outperforming their neurotypical counterparts (Table 1). These discoveries reveal that irrationality is not inevitable and offers the opportunity to specify the psychological and brain mechanisms that underlie both rational and irrational reasoning and **decision-making**. Here we review the evidence for **enhanced rationality** in ASD and consider the sources of potential variation in information processing that may mediate enhanced rationality. Enhanced rationality in ASD also has valuable implications for the understanding of human rationality and of **neurodiversity**, as consideration of areas of strength may lead to a more comprehensive understanding of ASD. {Although we use person-first language in this paper ('people with autism') following guidelines issued by the American Psychological Association and conventions of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) [1], we acknowledge that many people on the spectrum prefer identity-first language (i.e., 'autistic people').}

Human rationality: a brief overview

A well-known tension exists between traditional economic models of rationality and more contemporary investigations of human decision-making behaviors. According to traditional economic models, a rational agent should consider all relevant information when reasoning, reaching a decision or making a **judgment**. However, actual human decision-making behavior and the context in which it occurs are complex, and the ability to process all relevant information is constrained by memory capacity, processing speed, and other cognitive factors [2–4]. Therefore, observed human behavior often does not reflect the predictions put forward by traditional economic models.

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Table 1. Summary of evidence for enhanced rationality in autism spectrum disorder

Phenomena/cognitive bias tested	Findings	Population	Refs
Reliance on intuition	ASD group displayed reduced intuitive reasoning; more autistic traits associated with less intuitive and more deliberative reasoning	Clinical and nonclinical samples	[13,23,24]
Conjunction fallacy	Individuals with ASD less susceptible to influence of representative information regarding either people or items	ASD group versus a neurotypical control group	[19]
Attraction effect	Individuals with ASD and non-ASD individuals with high degrees of autistic traits show enhanced consistency in their choices	Clinical and nonclinical samples	[14]
Sunk-cost bias	Decisions of individuals with ASD are not influenced by costs that have been incurred and cannot be recovered	ASD group versus a neurotypical control group	[15,27]
Framing effect	Individuals with ASD display reduced effect of framing of options on choice selection	ASD group versus a neurotypical control group	[18,20]
Optimistic bias	Individuals with ASD learn equally from desirable and undesirable information	ASD group versus a neurotypical control group	[17]
Ultimatum game	Individuals with ASD likely to accept offers that are considered 'unfair' but economically beneficial	ASD group versus a neurotypical control group	[34–36]

Abbreviation: ASD, autism spectrum disorder.

In order to account for these discrepancies, Tversky and Kahneman posited that humans use cognitive shortcuts, or **heuristics**, to ease cognitive load when making judgments or decisions [5]. Heuristics allow people to reach decisions rapidly based on a rule of thumb, an educated guess, or an intuitive judgment, without fully processing every bit of available information algorithmically. Heuristics can be adaptive, allowing quick and effortless decision-making [6] or 'thinking fast' [7], but they can also lead to seemingly irrational behaviors [8–11]. As heuristics are sensitive to context, motivations, emotions, and aversions, they can lead to more bias-prone reasoning, suboptimal decision-making [4,5], and a host of cognitive biases.

Evidence for enhanced rationality in ASD

The idea that humans act 'irrationally' has influenced research and thought in psychology, economics, and other fields. Human irrationality is thought to reflect the boundaries of human information-processing capacity [2,12] and therefore provides insights into the human brain and mind. However, in the past several years, multiple studies have independently reported that individuals with ASD frequently display judgments that are more objective and decision-making that is less biased than that of **neurotypical individuals** [13–21] (Table 1). In this sense, the behavior of individuals with ASD might better reflect classic economic models of rationality than does the behavior of neurotypical individuals. This enhanced rationality in individuals with ASD is noted across domains and study designs. In particular, enhanced rationality in ASD seems to arise from reduced susceptibility to factors that typically confound rational thought and behavior, such as overreliance on intuition, overweighting of representative or irrelevant information, attraction to reward, and aversion to negative information.

Undue reliance on intuition

Reasoning is a necessary prequel to rational decision-making. Importantly, reasoning can often be confounded by intuition. For instance, imagine you are presented with the following

Glossary

Attraction effect: changing one's decision between two options based on the introduction of a third irrelevant choice, such that the choice that is most similar to the irrelevant one is considered more attractive.
Cognitive biases: systematic errors that derive from the use of heuristics and often result in suboptimal decisions.
Conjunction fallacy: assuming that multiple specific conditions are more probable than one more underlying condition due to the salience of representative information.
decision-making: the process of harnessing one's judgments, as well as personal preferences and other factors, in order to make a choice or select from among several options.
Enhanced rationality: a term we use to describe the behavior of individuals with ASD, who seem to use heuristics to a much lesser extent than neurotypical individuals when making decisions and thus are less susceptible to cognitive biases.
Framing effect: favoring one of two mathematically identical options because of the way they are framed or presented (e.g., as gain versus loss or positive versus negative).
Heuristics: cognitive shortcuts that allow reaching decisions or judgments without processing all the information available or in the absence of full information.
Irrationality: behavior that deviates from models of economic rationality, usually because of the use of heuristics.
Judgment: the process by which people construct an evaluation about other people or about a particular situation.
Neurotypical individuals: individuals who are not diagnosed on the autistic spectrum and often act as a control in studies with individuals with ASD.
Neurodiversity: the notion that variations in the human brain are part of a normal continuum rather than reflecting deficits and may even confer benefits.
Optimism bias: integration of desirable information and discounting of undesirable information to maintain an optimistic worldview.
Reasoning: the ability to process information in a logical manner.
Sunk cost bias: reaching a decision regarding a future investment (of money, time, or other resource) while

information: a coffee and pastry cost $1.10. The coffee costs $1 more than the pastry. How much does the pastry cost? An intuitive, and (surprisingly) wrong, response would be '$0.10'; the deliberative (and correct) answer is $0.05. For most people, the intuitive, or heuristic, response immediately 'jumps to mind' [22]. However, when asked questions such as the one above, individuals with ASD and neurotypical individuals with high autistic traits (Box 1) answer correctly more often than most neurotypical individuals [13]. This aligns well with the subjective experiences of individuals with ASD, who self-report a tendency to use intuition less when reasoning ([23,24], and see [13] for findings of both enhanced deliberation and decreased intuition). The association between autistic traits and reduced reliance on intuition may be one factor underlying enhanced rationality. As autistic traits typically measure challenges in social communication (Box 1), it is striking that they may also be associated with more rational reasoning patterns.

considering costs that have already been incurred and cannot be recovered, instead of considering only future potential for gains and losses.

Undue influence of seemingly relevant and irrelevant information

Reasoning and decision-making can be influenced by both information that is salient and seemingly relevant and information that is irrelevant. For instance, when making judgments, neurotypical individuals may incorrectly favor improbable explanations over more probable explanations due to the presence of highly representative information. This is evident in tasks examining the **conjunction fallacy** [10], wherein participants may be asked, for example, to read a description of 'Jerry,' a hardworking man who sits at a desk, makes telephone calls, and owns stocks. Participants then rank order the probability of multiple statements that describe Jerry's profession, one of which is a conjunction of two statements: 'Jerry is a broker,' 'Jerry is a plumber,' 'Jerry is a broker and a plumber,' 'Jerry is a zookeeper.' Strikingly, neurotypical individuals rank the conjunction of two statements ('Jerry is a broker and a plumber') as more likely than the less representative single statement ('Jerry is a plumber'), even though the probability of Jerry to have two jobs is mathematically smaller than having any one job. Individuals with ASD are less susceptible to the influence of representative information and consistently, and more correctly, rank the conjunction as less probable than the two independent elements of the conjunction [19].

Box 1. Autistic traits

'Autistic traits' refer to characteristics of autism that are continuously distributed across the population. Individuals with a diagnosis of autism would mostly cluster at the extreme end of this distribution, but there is continuous variance across the general population [81]. Several questionnaires are used to quantify such autistic traits. These questionnaires are not used for diagnostic purposes, because they are designed to quantify continuous variance in traits across all people rather than to delineate a clinical category.

The Autism Quotient (AQ)

AQ is a 50-item self-report questionnaire that quantifies autistic traits in children and adults [82]. Statements span different domains and include social preferences ('I prefer to do things with others rather than on my own'), imagination abilities ('If I try to imagine something, I find it very easy to create a picture in my mind'), communication ('Other people frequently tell me that what I've said is impolite, even though I think it is polite'), local-over-global processing ('I notice patterns in things all the time'), sensory sensitivities ('I often notice small sounds when others do not'), special or strong interests ('I tend to have very strong interests, which I get upset about if I can't pursue'), and ability to break a routine ('I prefer to do things the same way over and over again'). Participants indicate how strongly they agree or disagree with these statements on a 4-point Likert scale. One overall score is used to measure general autistic traits.

The Social Responsiveness Scale-2 (SRS-2)

Similar to the AQ, the SRS is a 65-item self-report questionnaire in which participants rate on a 4-point Likert scale how much each statement describes their behavior [83]. The SRS-2, however, is more focused on capacities associated with social abilities. In addition to a total score, the SRS-2 provides separate scores for the following subscales: Social Awareness ('I am usually aware of how others are feeling'), Social Cognition ('I do not recognize when others are trying to take advantage of me'), Social Communication ('I am able to communicate my feelings to others'), Social Motivation ('I would rather be alone than with others'), and Restricted Interests and Repetitive Behavior ('When under stress, I engage in rigid or inflexible patterns of behavior that seem odd to people').

Critically, individuals with ASD also show enhanced rationality when asked about situations with no social or person-specific context (i.e., descriptions of items rather than people), suggesting that well-documented difficulties in social cognition in ASD do not drive reduced susceptibility to representative information [19]. However, when tested on conjunctions that do not include salient or representative information (e.g., 'Jerry is a broker,' 'Jerry is a plumber,' 'Jerry is a zookeeper and a plumber,' 'Jerry is a zookeeper'), individuals with ASD rank conjunctions as more probable than they actually are, similar to neurotypical individuals [19]. Since according to the rules of probability, conjunctions are always the least likely descriptors when compared with single descriptors, this suggests that enhanced rationality in ASD in this domain is not driven by a better understanding of the rules of probability *per se*, but rather by less bias in the face of highly salient information.

Irrelevant information can also bias preferences and choices. For example, when individuals are asked about their preference between two competitive choices (e.g., ice cream or french fries) adding a third, clearly inferior, option (a decoy; e.g., a cracker), should not change one's original preference. However, neurotypical individuals' preferences are heavily influenced by expansion of the choice set with information that should not affect their preference and is therefore irrelevant. Changing the decoy can shift their preference toward the item that is most similar to the decoy ([25]; **attraction effect**). In effect, because french fries and crackers are in a more similar food group, a person who may have otherwise chosen ice cream is likely to change their preference to the french fries. Individuals with ASD and neurotypical individuals with high degrees of autistic traits show consistent preferences for the same item, regardless of an added decoy [14].

The propensity to integrate irrelevant information into the decision-making process when establishing preferences or choices is also expressed in the **sunk cost bias**, wherein decisions are irrationally influenced by costs that have been incurred, even if they cannot be recovered [26] (e.g., which trip to cancel if one costs more than the other but neither ticket can be reimbursed). Unlike their neurotypical counterparts, individuals with ASD are less susceptible to the influence of irrelevant information (e.g., are equally likely to cancel either trip regardless of cost) [15,27]. In sum, information processing seems to differ in individuals with ASD who may be better than neurotypical at distinguishing relevant and irrelevant information.

Undue attraction to reward and aversion to negative information

Human behavior is highly influenced by reward and negative outcomes, both of which are strong facilitators of learning. However, the tendency to be irrationally attracted to rewards and irrationally averse to negative information creates biases in information processing and decision-making. This is especially clear in tasks examining the **framing effect**, where neurotypical individuals favor options that are described as gains over options described as losses, even though the gain and loss are mathematically identical (e.g., 'lose $20 of $50' versus 'keep $30 of $50' [9]). Studies in ASD find that the magnitude of this preference is much smaller than in neurotypical individuals [18,20], suggesting more veridical information processing in ASD.

Similarly, in probabilistic learning tasks that manipulate reward frequency and magnitude, neurotypical participants favor high-frequency large rewards over high-frequency low rewards, even when the former are coupled with large losses, resulting in a net loss. In such tasks, several studies reported superior performance of individuals with ASD, who are less drawn to the immediate salience of rewards, and learn long-term reward contingencies more accurately from choice outcomes [21,28,29]. (However, see [30–32] for studies that did not find this advantage.)

An interesting exception to the salience of high reward is revealed in the ultimatum game, in which a person irrationally declines a reward in order to punish a partner who offers an unfair sharing of that reward [33]. Specifically, a 'proposer' makes an offer to the participant (the 'receiver') about how to split between them an amount of ten coins, given by the experimenter. Trials include either lower/'unfair' offers, wherein the participant is offered 10%–30% of the amount, or higher/'fair' offers, wherein the participant is offered 40%–50% of the amount. If the participant accepts the offer, both players benefit by receiving the specified rewards. If the participant rejects the offer, neither player receives any reward. In this configuration, it is economically rational for the receiver to accept any offer, even the lower ones. Neurotypical receivers, however, frequently reject lower offers to punish the proposer for what they feel is an unfairly small offer. Strikingly, a series of studies found that individuals with ASD act more rationally, as they are twice as likely as neurotypical individuals to accept offers that are considered 'unfair' but economically are more beneficial [34–36].

Lastly, neurotypical individuals also show a propensity to discount negative or undesirable information in learning. In studies examining this propensity, people initially estimate the likelihood of adverse events (cancer, robbery) to occur in their lives. Then, they are informed of the true probability of this occurring in the population, and subsequently asked to re-estimate their initial responses. When they learn that they initially overestimated their risk for an adverse event (desirable information), people adjust their re-estimates significantly more than when they initially underestimated their risk for an adverse event (undesirable information). This asymmetric discounting of undesirable information maintains an unrealistic optimism in the face of direct information about risk for negative events ([37]; **optimism bias**) and has been extensively replicated ([38–41], although see [42]). Individuals with ASD, however, process information more objectively by displaying no differences in learning from desirable versus undesirable information [17]. Across domains of intuition, reward, and information, individuals with ASD exhibit more objective and rational reasoning and decision-making. Interestingly, reduced reliance on intuition and less integration of emotion, which are typically thought to play a significant role in core ASD challenges such as social communication, may in fact contribute to ASD enhanced rationality.

Candidate theoretical and empirical mechanisms for enhanced rationality in ASD

Although ASD is primarily characterized by challenges across social, linguistic, and motor domains, several empirical studies have identified 'islands of ability' in domains ranging from vision [43] to music [44]. Some existing theories and frameworks of ASD account for both challenges and islands of intact ability. Whether these frameworks may be relevant to enhanced rationality demonstrated by individuals with ASD has not been explicitly tested. Here we describe empirical evidence and theoretical frameworks that may provide mechanistic accounts of enhanced rationality in ASD.

Reduced interference of emotions and reward on reasoning and decision-making in ASD

In neurotypical individuals, several studies exploring the neural basis of cognitive biases find that increased brain activations in limbic (e.g., amygdala) and reward areas, associated with emotional and motivational processing of information, respectively, may underlie irrational decision-making (Box 2). It has thus been suggested that in individuals with ASD, differences in emotion or motivational processing may contribute to more rational decision-making [17,18,45]. Indeed, problems with identifying, processing, and integrating emotion are included in the diagnostic criteria for ASD [101], and reduced amygdala activation and structural differences in the amygdala are frequent findings in ASD [46–48]. In addition, individuals with ASD often display reduced brain activation for rewards, ranging from money to social stimuli [49,50].

Box 2. Neural mechanisms of cognitive biases in neurotypical individuals

In neurotypical individuals, neuroimaging studies find that susceptibility to cognitive biases is associated with increased engagement of limbic and reward systems (associated with emotional and motivational evaluation of information, respectively). For example, framing options in terms of wins or losses can elicit differential engagement of the amygdala – a core hub of the limbic network important for emotion. fMRI studies in neurotypical individuals find that when deciding between a 'sure option' or a 'gamble,' amygdala activation tracks the tendency to be risk averse when options are framed as gains and risk seeking when options are framed as losses. Importantly, decreased susceptibility to the framing effect is associated with activation in prefrontal regions, the orbital and medial prefrontal cortex (PFC), crucial for decision making and evaluation of information [84]. Similarly, brain regions involved in integrating desirable information over undesirable information (the optimism bias) can provide insight into the mechanisms that underlie irrationality and enhanced rationality. Studies examining the optimism bias find that the tendency to integrate desirable information is associated with activation in reward systems. Increased activation in the ventral striatum (a region involved in reward and motivation) is associated with relative neglect of undesirable information, whereas activation in the PFC (ventromedial PFC, important for valuation of rewards) is associated with the integration of desirable information [85,86]. These results suggest an important role for emotion- and reward-mediating structures and their interactions with the PFC in weighing incoming information and making rational and irrational decisions.

While altered structure and activation in limbic and reward brain regions may contribute to difficulties in emotion and reward processing in ASD, they may also confer advantages in the context of decision-making by by reducing the influence of reward and emotion on cognition. In turn, such reduced influence may allow ASD individuals to weigh negative and positive information more equally. In fact, one study found that unlike neurotypical individuals, ASD individuals do not exhibit differential physiological responses (as measured with galvanic skin response) for losses versus gains during decision-making [18]. On the other hand, another study found that when controlling for difficulty identifying emotions (i.e., equal levels of alexithymia between ASD and neurotypical groups), ASD individuals are still less influenced by the framing of loss versus gain [20]. These findings imply that reduced integration of emotion into decision-making processes, but not altered identification of emotions, may contribute to enhanced rationality in ASD. Future studies are needed to elucidate the physiological and neurobiological basis of ASD enhanced rationality. For example, less discrepant activation patterns in limbic and reward regions during decision-making may allow ASD individuals to weigh information objectively and be more resilient to cognitive biases driven by reward or to information that engenders strong emotions.

Reduced interference of emotions and reward as a theory to explain ASD enhanced rationality is compelling, as it builds on both specific ASD diagnostic criteria and decades of research into brain differences in ASD. However, ASD individuals also display more rational and less intuitive choice selection (e.g., in the attraction effect or conjunction fallacy) when emotions and reward do not seem to be involved. In these cases, it is possible that systems and brain regions important for reward may also subserve other functions. For example, the basal ganglia, a group of nuclei relevant for reward processing, are also implicated in probabilistic learning and executive functions [51]. Future research should determine whether differences in brain systems involved in cognitive bias may be related to enhanced rationality even when there are no clear links to emotion or reward.

Reduced influence of context and prior knowledge, and enhanced attention to details

A multitude of studies find that individuals with ASD have trouble taking advantage of context or prior knowledge to adapt to new situations. Examples range from reduced adaptation to recurring auditory stimuli [52] to reduced benefits of semantic context when attempting to understand ambiguous words [53]. Relatedly, individuals with ASD display increased attention to details, often reflected by an increased propensity or desire to understand the specific rules and details that govern a system (i.e., systemizing [54]), and slower, more deliberative processing speed when making decisions [13,55–57]. These observations have spurred several theoretical frameworks positing that when processing incoming sensory input, individuals with ASD systematically rely less on context or prior

knowledge and more on the details and specifics of the input (central coherence theory [58], predictive coding theory of autism [59,60]). This shifted balance between the specifics of the input and the context in which it is perceived has been suggested to explain both challenges (e.g., hypersensitivities [61]) and strengths (e.g., superior visual search [43]) in ASD [62].

The information-processing differences suggested by these frameworks could apply to the advantage of individuals with ASD in the context of enhanced rationality. In neurotypical individuals, the use of context or prior knowledge allows rapid, although biased, decision-making. With lesser influence of context or prior knowledge, individuals with ASD may consider each piece of information independently, rather than applying a heuristic (generalizing) or being influenced by intuition (prior knowledge) [45]. Such attention to details over reliance on prior knowledge could lead to reduced susceptibility to cognitive biases and thus to enhanced rationality. In fact, in the sensory domain, reduced influence of context or prior knowledge and enhanced attention to details is thought to underlie reported reductions for perceptual biases in individuals with ASD ([63–65]; however, see [66,67]). Reduced susceptibility to cognitive biases may parallel reduced susceptibility to perceptual biases in ASD.

Among these explanations, a mechanism that entails a shifted balance between attention to details and influence of context and prior knowledge is perhaps the most compelling mechanism to explain ASD enhanced rationality while accounting for additional core challenges in ASD [45,59,68]. Future studies should further empirically test for an association between reduced susceptibility to biases in the cognitive and sensory domains in ASD by measuring several of these biases simultaneously in the same participants. Studies should also take into consideration variation among individuals with ASD instead of considering them as a homogeneous group. In addition, comparing enhanced rationality in ASD with other diagnostic groups, such as people with depression, may also be illuminating and also directly relevant for ASD because of the high rates of co-occurrence of anxiety, depression, and ADHD in ASD (Box 3).

Of course, it is possible that multiple brain and behavioral differences in ASD (emotional, reward-based, attentional, contextual, etc., as discussed above) combine to enhance rationality and that the relative contributions of these factors vary in relation to specific kinds of reasoning and decision-making (e.g., whether a decision invokes reward or emotion or relies on context or intuition) (Figure 1).

Box 3. Enhanced rationality in other clinical disorders?

Cognitive biases in information processing differ not only in people with ASD but also in people with other psychiatric diagnoses (for a recent book reviewing related evidence, see [87]). This may allow enhanced rationality in additional populations. For example, individuals with depression exhibit 'depressive realism' [88] in which they exhibit more accurate ratings than individuals without depression about their control over outcomes in an experiment [89]. Enhanced accuracy in depression is further documented by reduced susceptibility to visual illusions [90]. In addition, similar to individuals with ASD, depressed individuals display a diminished or absent optimism bias, meaning that they integrate information objectively, regardless of whether the information is desirable or undesirable [91]. However, additional studies of potentially enhanced rationality in depression are sparse and yield conflicting findings (e.g., ultimatum game: evidence in favor [92] and against [93] more rational game strategy in depression). The reduction of the optimism bias and other biases in depression [94,95] can result in more accurate judgments, but some of these biases may be conceptualized as typically supporting mental health, and their reduction or absence may contribute to reinforcing the negative thought pattern that is a core symptom of depression [96].

The evidence that depression or perhaps other psychiatric diagnoses may be associated with alterations in cognitive biases is additionally relevant for ASD because there are high rates of co-occurring diagnoses or symptoms in ASD. It is estimated that among individuals with ASD, ~40% also meet criteria for anxiety, 12% for depression, and 30% for ADHD [97,98]. Future studies may examine whether these co-occurring symptoms are related to various forms of enhanced rationality in ASD.

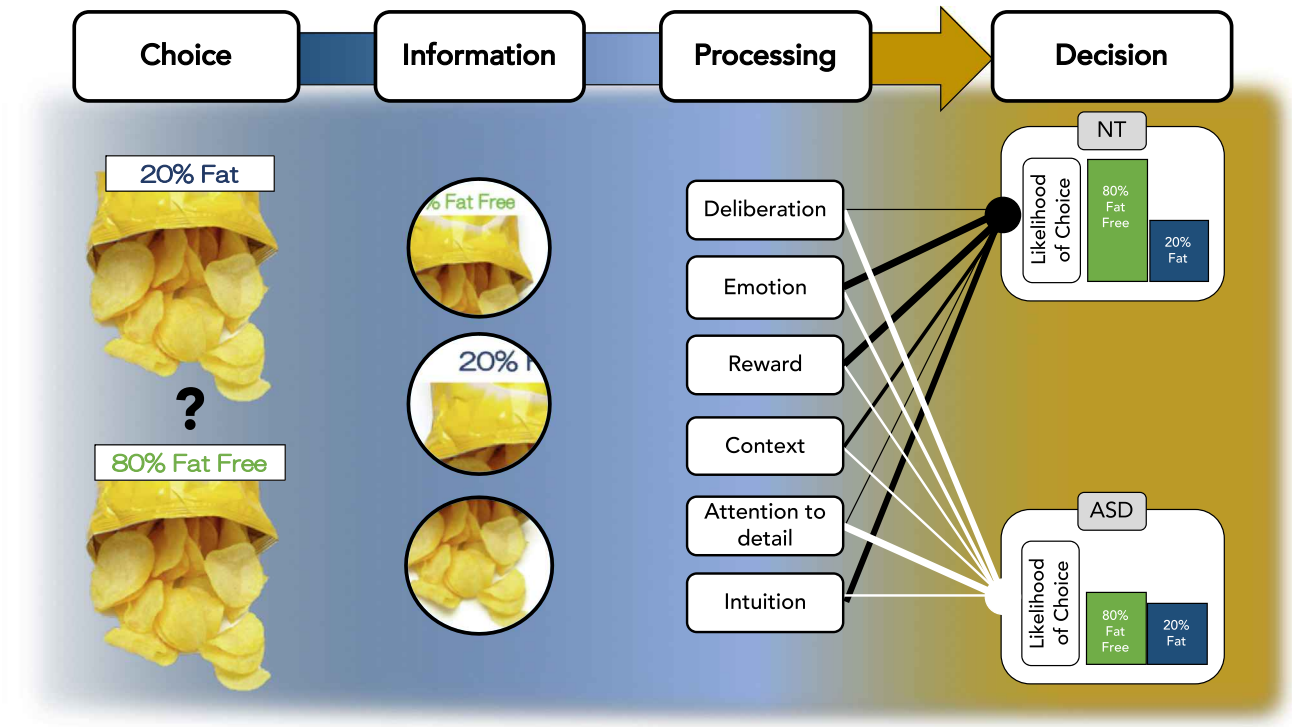

Figure 1. From choice to decision. When faced with a choice, different factors cause people to process and integrate certain aspects of incoming information and ignore others, thus biasing decision making. Some known or hypothesized factors influencing decisions are emotion, reward, intuition, context, deliberation, and attention to detail. For example, in the case of the framing effect, when choosing between two mathematically equal options (80% fat free versus 20% fat), it is possible that such factors differentially influence decisions in neurotypical individuals and in individuals with ASD, who are known to exhibit reduced framing effects. In this hypothetical example, some of these factors may allow individuals with ASD to avoid the typical attraction of a positively framed (80% fat free) but mathematically identical choice and make a decision that is less biased and therefore more rational. The thickness of the lines (black = NT; white = ASD) depicts the degree to which each of the different factors could influence decision making. Abbreviations: ASD, autism spectrum disorder; NT, neurotypical.

Extension of ASD enhanced rationality to the social domain

The distinction between rational and irrational behavior is well defined in the above cognitive paradigms in which ASD individuals have often shown enhanced rationality. That distinction is less clear-cut in social judgments, a domain in which individuals with ASD often show everyday difficulties. There are, however, some intriguing findings of differences in several kinds of social judgments in ASD. For example, several studies suggest that individuals with ASD show typical explicit understanding and use of social race and gender stereotypes [69–72]. In contrast, implicit bias based on race and gender appears to be reduced in ASD [69,71]. These findings may imply that the presence of intact knowledge of culturally transmitted stereotypes does not necessarily predict biased social decision-making in ASD, as it would in the neurotypical population [73]. Reduced application of cultural stereotypes could be interpreted as a form of enhanced rationality in social reasoning, judgment, and decision-making.

In line with this notion, people with higher autistic traits in a large-scale, nonclinical sample show improved ability to predict social psychological phenomena, such as social projection and groupthink [74], when applied generally to people, as opposed to specific individuals (as in classic theory of mind studies). Furthermore, the relationship between higher autistic traits and better social

Box 4. Representation of the autism spectrum in studies of enhanced rationality

The full spectrum of ASD is extremely wide, varying from individuals who are nonverbal and/or have intellectual disabilities to individuals who are verbally fluent and cognitively skilled. Across behavioral and neuroimaging research on ASD, there is a strong selection bias that results in an over-representation of individuals with ASD who are comparable to neurotypical individuals in their language and cognitive skills [99,100]. This over-representation occurs because behavioral and neuroimaging research requires multiple abilities to follow instructions and perform complex tasks. This may be especially salient for studies revealing enhanced rationality in individuals with ASD, because such studies involve relatively complex exercises in reasoning, judgment, and decision making. (Indeed, that complexity is related to why neurotypical individuals so often employ heuristic shortcuts to avoid more careful and accurate analysis.)

This practical inclusion bias prevents the enhanced rationality observed in the reviewed studies of ASD from being generalized to the entire ASD community (see Outstanding questions). Researchers are encouraged to find creative paradigms to test these abilities in a more representative range of the ASD community.

cognitive judgments is mediated via systemizing abilities, indicating how principles from an ASD enhanced rationality framework, such as the ability to learn regularities, may project to the social domain. Judgments about social psychological phenomena, however, have not yet been assessed in individuals with ASD diagnoses.

Individuals with ASD also show differences in moral judgments that are not as easy to categorize in terms of rationality. For example, compared with neurotypical individuals, individuals with ASD rely more on behaviors and outcomes than on a person's intentions or characteristics when making moral judgments [75,76]. Although it is more conventional for moral judgments to give weight to consideration of a person's intention and characteristics, it is unclear if it is more rational to do so instead of judging a person's actions by the consequences of those actions on other people. These differences in moral judgments in ASD apply not only to another person's behaviors but also to one's own behavior, as individuals with ASD are more likely to reject self-serving choices supporting bad causes than neurotypical individuals [77].

Concluding remarks

The consistent evidence of enhanced rationality in ASD provides both scientific opportunities and translational opportunities for the ASD community. In regard to science, systematic irrationality (in thinking faster via heuristics) has been understood as an inevitable characteristic of the human mind and brain. Enhanced rationality in ASD shows that this is not true and offers the chance to study psychological and neural mechanisms that mediate both rational and irrational thought and behavior (see Outstanding questions).

In regard to autism, enhanced rationality addresses concerns that research on ASD has focused on difficulties rather than differences in ASD [78–80]. This is partly justified by the difficulties that many individuals with ASD and their families face. Enhanced rationality, however, can be viewed as a strength of individuals with ASD, albeit most salient for individuals with ASD who have other cognitive and language strengths (Box 4). Characterizing these strengths can help identify pathways for flourishing with ASD. For example, nearly half of individuals with ASD turning 18 years of age in the USA will not hold a paying job until the age of 25 years. This is the lowest rate of any other diagnostic category, and this number grows by 100 000 teenagers each year (https://www.autismspeaks.org/autism-statistics). There must be many job categories where enhanced rationality is a valuable strength, and mapping enhanced rationality to those job opportunities ought to be beneficial for ASD individuals and employers alike.

Outstanding questions

Can we use neuroimaging to help understand the brain mechanisms reflecting the different thinking processes in ASD versus neurotypical individuals, such as to distinguish between reduced emotional and motivational decision-making and enhanced reasoning abilities?

Is reduced susceptibility to biases in ASD correlated with any of the other behaviors that are related to the theories that are suggested to account for ASD enhanced rationality? Examples of such behaviors include enhanced performance on tasks that require attention to details or reduced effect of context in other domains, such as perception, that are thought to account for both strengths and challenges in autism.

What specific cognitive abilities may contribute to enhanced rationality in ASD? Do any emotional biases support enhanced rationality, such as different attentional biases in ASD?

How instrumental to enhanced rationality are high-level cognitive abilities? In other words, would individuals on the autism spectrum with reduced cognitive abilities be able to display similar abilities in some of the biases we reviewed (Box 4)?

Given that heuristics allow neurotypical individuals to make rapid but suboptimal decisions, what are the costs of enhanced rationality in ASD? Is enhanced rationality associated with any of the challenges in ASD, and are those challenges driven by a more analytic and less intuitive thinking style?

What other processes in the social domain may benefit from the principles of ASD enhanced rationality?

Is enhanced rationality evident in childhood and adolescence? If so, does such enhanced rationality influence other aspects of social or cognitive development in ASD?

Does a comorbidity of other diagnoses (e.g., anxiety, depression) interact with ASD in the domain of enhanced rationality? Future studies should adopt a transdiagnostic approach to disentangle possible shared influences (Box 3).

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Declaration of Interests

The authors have no interests to declare.

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