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Common outcome, different pathways: Social information-processing deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder

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Abstract

Social functioning is a key domain of impairment in both autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD). This review adopts the social information-processing model as the theoretical framework to compare and contrast the deficits of ASD and ADHD at each of the six steps of social information-processing. Both disorders show deficits at each step, but the nature and origins of the deficits are different. Thus, while both disorders exhibit a common outcome of social impairment, the exact pathways that each disorder traverses along the six steps of social information-processing are different. For ASD, there is a social knowledge/behaviour deficit arising from difficulties in social/emotional cue detection, encoding, and interpretation, leading to problems in joining and initiating social interaction. For ADHD, there is a performance deficit incurred by disruption arising from the ADHD symptoms of inattention and hyperactivity/impulsivity, while its acquisition capacity on social knowledge is relatively intact. The inattentive, intrusive, and impulsive behaviours of ADHD unsettle social interaction. Finally, this review proposes training targets for intervention along the six steps of the social information-processing model for ASD and ADHD, as well as areas for future research in further elucidating the social impairment of the two disorders.

Key Words: Autism spectrum disorder; Attention deficit/hyperactivity disorder; Social information-processing; Social impairment; Social skills training; Social outcome

Core Tip: Both autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) show deficits in social information-processing, but their nature and origins are different. While both disorders exhibit a common outcome of social impairment, the exact pathways that each disorder traverses along the social information-processing steps are different. For ASD, there is a social knowledge/behaviour deficit arising from difficulties in social/emotional cue detection, encoding, and interpretation, which lead to problems in joining and initiating social interaction. For ADHD, there is a performance deficit incurred by disruption arising from the ADHD symptoms of inattention and hyperactivity/impulsivity. The inattentive, intrusive, and impulsive behaviours of ADHD unsettle social interaction.

INTRODUCTION

Social functioning is a key domain of impairment in both autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD)[1]. For the diagnosis of ASD, social impairment is a defining feature and a core diagnostic criterion. Findings consistently indicate significant deficits in fundamental aspects of social cognition including weakness in emotion recognition skills and theory of mind compared to typically developing peers. These in turn are significant contributing factors for suboptimal social behaviour and social outcome in ASD.

Social impairment is also well-documented in children with ADHD and has often been conceptualized as a manifested outcome of its core symptoms of inattention, hyperactivity, and impulsivity. Children with ADHD demonstrate a failure to modulate behaviour according to the social contexts and more frequently engage in inappropriate social behaviours such as paying less attention to peers (inattention) or interrupting others out of turn (impulsivity) during their social interactions[2,3]. These problems in social behaviours are seen as contributed by ADHD symptoms, giving rise to inconsistent or inappropriate behavioural responses and regulation[2,4], and often result in higher rates of peer rejection and friendship failures.

Since both children with ASD and those with ADHD present with social impairment, it is important to better understand the processes that underlie this common outcome between the two disorders. A recent review by Mikami *et al*[1] extensively examined the characteristics and aetiologies of social impairment in these two disorders. Across the broad domains of social functioning including social cognition, social behaviour, and peer regard, it was found that both ASD and ADHD shared transdiagnostic impairment in all of these areas, yet were also distinct in the different areas of difficulties. For instance, while both disorders exhibited problems in peer regard, the social difficulties of ADHD were characterized by disruptive and negative behaviours in peer situations, while ASD children might lack the positive or prosocial behaviours to initiate and maintain peer relationships. In other words, there is a distinctiveness of deficiency in knowledge and skills in ASD compared to relatively intact skills but problematic performance in ADHD. While this recent review describes well the potential different bases of deficits leading to impairment in overt social behaviours across the two disorders, it has not organized the underlying deficits under a coherent and comprehensive theoretical framework of social information-processing that characterizes in sequential steps how an individual first attends and processes incoming stimuli in a social situation, including the thoughts and feelings of others, to be followed by decision-making, and then choice and enactment of an appropriate social response at the end. These underlying social cognitive processes are the mechanisms and pathways that translate a social situation into a social outcome. A social information-processing model, proposed by Crick and Dodge[5], has been put forward to explain social behaviours with a series of hierarchical, stepwise cognitive processes that serve the above-described cognitive functions in responding to social situations or events. This series of cognitive processes, which are based largely on biologically determined capabilities in social cognition, as well as past learning experiences, shape the eventual social interaction. Thus, any deficits along this hierarchy of sequential steps can contribute to social impairment[4].

This review will adopt the social information-processing model by Crick and Dodge[5] as its theoretical framework, which is well-defined and well-tested, to elucidate the social cognitive processes that underlie the common outcome of social impairment in ASD and ADHD. The identified deficits can become viable training targets to be alleviated for enhancement of social behaviours in ASD and ADHD.

THE SOCIAL INFORMATION-PROCESSING MODEL

The social information-processing model proposed by Crick and Dodge[5] describes a hierarchy of covert, mental mechanisms that are employed to translate external social cues (inputs) to overt behavioural responses (outputs). It provides a theoretical framework to better understand the social cognitive abilities and social adjustment of children. The model includes five cognitive steps followed by the sixth step of behavioural response enactment: (1) Encoding of internal and external social cues; (2) Interpretation and mental representation of cues; (3) Clarification or selection of goals; (4) Response construction; (5) Response decision; and (6) Behavioural enactment[5,6]. Each step is guided by biologically determined capabilities in cognitive functioning, as well as a memory database of learned social experiences, which informs of social rules, schemas, and knowledge/skills of social behaviours.

Upon encountering a social situation, children enter the initial steps of social information-processing, whereby they selectively attend to, encode, and interpret social cues (steps 1 and 2). Essentially, steps 1 and 2 help the children create a mental representation of the presenting social situation or event - what is happening (attend and encode) and why it is happening (interpretation), including inferences about the perspectives and intentions of others involved. Deficits in these early stages of social information-processing, such as inaccurate encoding and interpreting of social cues, can create a biased mental representation of the social situation upon which behavioural responses are chosen for.

After creating a mental representation, children clarify and select a goal or desired outcome for the social situation in step 3. For instance, if they encode aggressive cues and interpret the situation as provocative or hostile, the children may determine whether their goal is to get even or avoid the provocation; whilst if they interpret the situation as friendly, the children may then consider more pro-social goals. The intention is to produce certain desired outcomes in a social situation.

After the children clarify their goals, they then need to construct a range of potential behavioural responses (step 4), either selecting from their existing pool of behaviour repertoire or generating a new piece of behaviour if the situation calls for it due to its novelty. Subsequently, at step 5, children evaluate their response choices and decide upon the most appropriate behaviour based on various expectations, including outcomes expectation, sense of self-efficacy and response appropriateness. Finally, at step 6, the chosen response is behaviourally enacted, producing a social outcome. Yet, children may produce suboptimal social responses should they have very limited behaviour repertoire, bad judgement on evaluating and deciding on the appropriateness of the responses, or over/underestimation of their self-efficacy in enacting the responses to the social situation. All these lead to impairment in social interaction.

Role of emotions in social information-processing

Crick and Dodge[5]'s model also recognizes the importance that emotions play in social information-processing by highlighting the interactions between emotions and cognitions[7]. Each step of the social information-processing is intertwined with emotional processes. The biologically determined cognitive capabilities and the memory database of past learning experiences that guide social information-processing also include a predisposition to emotionality. The emotional states will affect the children's mood-congruent cued recall of past experiences, for instance, which in turn affects the information-processing. In encoding and interpreting cues, emotion recognition ability can play an important role in which emotion cues become encoded and interpreted; as such, inaccurate or selective encoding and interpretation of others' emotions, such as the tendency to encode and interpret ambiguous cues as anger, may generate more hostile responses than if the cues were encoded and interpreted as more neutral. The encoding and interpretation of cues can also be influenced by pre-existing mood states and levels of emotional arousal during the interaction, such that children are more likely to notice and recall mood-congruent information. Emotions can also have an impact in the determination of goals and the construction and choice of behavioural responses, whereby children with high emotional reactivity may choose goals and responses that primarily help to reduce emotional arousal, such as avoidant or hostile goals and actions. Children who are weak in reading and interpreting others' emotional cues, on the other hand, may tend to determine goals and choose responses that are less considerate of others' emotions and less likely to maintain relationship. Overall, while the social information-processing model describes primarily a social cognitive mechanism to explain social outcomes, there is a strong interplay with emotional processing, such that differences in emotionality or emotion recognition can influence each step of social information-processing toward the outcomes.

Studies of social information-processing in children

Children with both externalizing and internalizing problems have been found with deficits along each step of the social information-processing model. For example, children with externalizing problems such as aggression were more likely to attend and encode cues related to aggressive or aversive acts in social situations (step 1)[8]. When interpreting social cues (step 2), aggressive children, as compared to non-aggressive peers, also showed hostile attributional biases and viewed others' actions and motivation as driven by hostile intent even when the situations were presented as ambiguous[5,8]. Research comparing behavioural responses of children with and without externalizing problems also

found differences in the quality and quantity of responses/solutions generated, whereby aggressive boys produced fewer assertive responses to solve social difficulties, but with an increased likelihood to engage in direct aggressive actions if the situations involved hostile provocation (steps 4-6).

Children with internalizing problems are also found with ineffective social information-processing patterns when compared to socially adjusted children. Depressed children, for instance, were less accurate in encoding relevant social cues and showed hostile attribution biases when interpreting social cues in unfamiliar situations (steps 1 and 2)[5,9]. In terms of behavioural responses, depressed children viewed assertive responses as associated with less positive and more negative outcomes, and thus tended towards constructing fewer assertive responses (steps 4 and 5)[10].

Conversely, social information-processing patterns for prosocial behaviour in children showed that they were more likely to interpret social cues positively, with a preference for maintaining positive relationship in the goal clarification step (step 3) even in face of provocation. Children who were accepted by their peers provided more prosocial and effective solutions and responses than children of lower peer status (step 4)[11].

Overall, the literature demonstrates that the social information-processing model by Crick and Dodge [5] is a helpful theoretical framework for understanding the underlying cognitive and behavioural processes contributing to differences in social behaviours and outcomes in children. It highlights the hierarchical nature as well as the interconnectedness of each step of the processes in contributing to the effectiveness and appropriateness of social responses to social situations, and how deficits in any of the steps can culminate into problematic social behavioural outcomes. It has proven validity in explaining and predicting externalizing, internalizing, and prosocial behaviours. This review will adopt this model to elucidate how the social information-processing deficits of children with ASD or ADHD can lead to their social impairment in six steps.

SOCIAL INFORMATION-PROCESSING DEFICITS IN ASD AND ADHD

Although the social information-processing model by Crick and Dodge[5] has been applied to study the social deficits in ASD and ADHD, the number of available studies has not been plentiful. Furthermore, most studies conduct their investigation separately with ASD and ADHD; studies directly comparing the social information-processing patterns of the two disorders remain sparse to date. One general consensus emerging in the literature is that social information-processing deficits do emerge in ASD and ADHD, and they in turn contribute to the social impairment of both disorders. However, as we systematically review below studies at each step of social information-processing, the deficits identified are of different nature for ASD and ADHD, providing insight into how these disorder-specific deficits, though traversing different pathways along the hierarchically determined steps of social information-processing, eventually cumulate into a final common outcome of social impairment for both disorders.

Step 1: Encoding of social cues

Cue encoding and detection: Cue encoding is the first step in social information-processing. A commonly used assessment tool for examining cue encoding is the social information processing interview (SIPI). It is a structured interview based on a series of vignettes or stories depicting negative peer social interactions (peer rejection or provocation). Children with ASD were found to score significantly lower on the efficient coding score of the SIPI, which measured the average level of details that could be accurately recalled by the children regarding the presented vignettes[6]. This indicated that children with ASD were encoding social information less accurately. This could potentially be due to their remembering fewer details (*i.e.*, encoding fewer cues) or remembering the details inaccurately (*i.e.*, tendency to code irrelevant cues), or both. Unfortunately, such error patterns were not captured by the SIPI and thus not reported. Nonetheless, the inefficiency in cue encoding by children with ASD means that they will in turn generate a less accurate mental representation of the social situations.

Children with ADHD were consistently found to encode fewer cues compared to control children when presented with the social vignettes[12]. Furthermore, they encoded lower percentages across positive, negative, and neutral cues, indicating that the inefficiency was non-specific and present across all valences[13]. Difficulties in attention and working memory, two fundamental deficits underlying ADHD symptomatology, were suggested for this non-specific pattern of inefficiency in cue encoding[12, 13]. It was hypothesized that children with ADHD might miss noticing cues due to inattentiveness or might fail to encode all relevant cues due to working memory deficit (*i.e.*, forgetting or failing to recall details of the social vignettes). Once again, the inefficiency in cue encoding in children with ADHD hinders them from developing a more balanced and accurate mental representation of the social situations.

Overall, cue encoding deficit is identified in both ASD and ADHD. However, since these findings are from separate studies, which use different (though similar) measures of cue encoding, it is difficult to conclude if the findings are directly comparable. Researchers also seem to speculate different origins of the encoding inefficiency in the two disorders. For the children with ASD, it is a fundamental deficit of ASD in encoding social cues, while the cue-encoding inefficiency of children with ADHD is a by-

product or a result of interruption arising from their ADHD symptoms, *i.e.*, inattention and working memory deficit.

Social perception/cognition: Those rare studies which directly compared social perception/cognition between ASD and ADHD suggested a more severe social perception/cognition deficit in ASD but a milder deficit in ADHD[14,15]. In particular, the evidence seems to suggest a larger contributing role of neurocognitive factors in social perception/cognition deficit in ADHD than ASD. Baribeau *et al*[15] compared the social perception/cognition abilities of children with ASD, ADHD, or obsessive-compulsive disorder and typically developing children using the Reading the Mind's Eyes test (RMET), a standardized test on decoding mental states which was based upon matching photographs of eyes with corresponding emotions and mental states being portrayed. Children with ASD were found to exhibit the most significant social perception/cognition deficit compared to other groups, while children with ADHD were found to display an intermediate level of social perception/cognition deficit, falling between the ASD and control groups in their performance. Furthermore, after controlling for intelligence quotient (IQ), there was a narrowing in the performance gap between the clinical groups and typically developing children. In particular, the accuracy scores of ADHD children became comparable to those of typically developing children. Drawing from these results, it seems that a large part of the social perception/cognition deficit in ADHD can be explained by lower general cognitive abilities, since ADHD children do have a lower IQ compared to typically developing peers[16]. For ASD, however, the effect of IQ can only explain part of the deficit. In the same study, features of hyperactivity and impulsivity were also found to be associated with deficit in social perception/cognition for all participant groups regardless of diagnosis; ADHD traits as measured by the strength and weaknesses of ADHD and normal behaviour rating scale had a significant negative effect on the RMET scores. The adverse impact of ADHD features in social perception/cognition was further substantiated by findings indicating that stimulants improved social perception/cognition in ADHD [14].

Another important differentiating factor when comparing social perceptual/cognitive deficits in ASD and ADHD is age. While paediatric samples demonstrated moderate effect sizes in social perception/cognition deficits for both ASD and ADHD, the effect sizes became smaller for adult ADHD samples, suggesting age-related improvement and catching-up in social perception/cognition for ADHD as aged. Conversely, this age-related improvement was not found among the ASD population[14]. These differential findings across age support the speculation that social information-processing deficits of ADHD may be by-products of ADHD symptomatology whose age-related improvement also results in correspondingly age-related improvement in social perception/cognition.

Facial emotion recognition: Emotion recognition has been included as a fundamental process in social information-processing within the first step of cue encoding[7]. The encoding and interpretation of others' affective cues are an important source of information for processing. Facial emotion recognition has been studied extensively in ASD. The ability to recognise and discriminate facial emotional expressions is present in infants as young as 10 wk of age, but it is a key generalized deficit or delayed ability in children with ASD across all facial expressions, and may vary in magnitude for specific emotions, with more difficulty in the recognition of negative emotions, particularly fear and anger[17-19]. It persists through to adulthood[20]. This suggests a failure to develop specialization and expertise in emotional processing in ASD, and despite investing in efforts and resources to compensate, children with ASD are still unable to catch up in adulthood.

Findings on emotion recognition in ADHD also suggest weaker emotion recognition capability[19]. Yet, it has been speculated that emotion recognition deficit in ADHD may be due to a failure to attend to the appropriate cues of affect incurred by the inattention symptom of ADHD. In a study examining emotion recognition, it was found that boys with ADHD showed poorer performance across all tasks regardless of whether facial emotions were involved, indicating a more generalized difficulty involving deficit in attention control[21]. Furthermore, other studies found random error patterns and increased performance variability on emotion recognition performance for children with ADHD as well, which further implicated the role of inattentiveness in emotion recognition performance (*e.g.*, momentary lapses of attention characteristics of ADHD)[12,19]. Conversely, among children with ASD, performance in emotion recognition tasks was less variable with no random or variable error patterns[19], suggesting a performance profile less affected by momentary lapses of attention as in ADHD. These findings suggest a more pertinent role of inattentiveness in emotion recognition performance in children with ADHD, but not in children with ASD.

Yet, some studies do find inattention or distractibility as an important covariate for explaining facial emotion recognition deficits in both ASD and ADHD. However, it should be noted that in some of these studies, children with ASD were included regardless of the presence or absence of comorbid ADHD symptoms. For instance, in one study, up to one-third of the cases with a primary ASD diagnosis also fulfilled the criteria for ADHD[19]. Furthermore, the presence of ADHD aggravated the facial emotion recognition performance, including increased variability, in comorbid ASD and ADHD children, highlighting once again the negative role of inattentiveness in emotion recognition performance[22].

Step 2: Interpretation of cues

Interpretation of cues involves attribution processes in which children make inferences about causal relationships, intents of others, *etc.* Children with ASD or ADHD have been suggested to show attributional biases in cue interpretation. A common and well-researched cognitive bias is the hostile attribution bias, which is the tendency to attribute malevolent or hostile intents when interpreting ambiguous or neutral social scenarios. For instance, preschool children with ASD were found to frequently interpret actions of others as hostile, which then led to the enactment of more aggressive responses[6]. However, the same bias was not consistently found among school-aged children and adolescents with ASD[23]. Instead, adolescents with ASD were more likely to show a negative, global attribution style in which they were more likely to view social outcomes as independent of their responses, making them less likely to assert prosocial responses but avoid or withdraw from interaction when faced with social situations[24]. The study reasoned that those repeated experiences of negative social interaction experienced by children with ASD, due to the well-known weakness in theory-of-mind in ASD, could lead to this negative, global attributional bias.

Attribution bias has also been studied among children with ADHD. They appeared to rely more heavily on their own opinions on what was happening in the social situations rather than on the observable, factual information[13]. This was suggested to be related to attentional problems, which hampered upstream cue encoding, contributing to fewer cues being encoded. Having less factual information to rely on, children with ADHD subsequently had to rely more on personal opinions. They were also more likely to show a recency effect when interpreting social situations by using the most recent contextual information[12]. This shallow interpretative process might also be related to attentional problems and working memory deficits, such that they were unable to hold and mentally manipulate all of the social cues, thus only relying on their most recent memories. Furthermore, a hostile attribution bias was generally not found in children with ADHD by comparison to typically developing peers[25,26]. Instead, children with ADHD were suggested to have a positive illusory attribution bias, whereby they tended to overestimate their abilities, leading them to choose unattainable or overly ambitious behavioural responses, as well as to underestimate their problems in the actual social situations. Such bias made the children with ADHD to be rated as less friendly, more inattentive, and less engaged in social situations[12].

Overall, in terms of cue interpretation, both ASD and ADHD show attribution biases, though the type of attribution biases and the underlying contributors differ between the two disorders. Children with ASD are more likely to show a negative, global attribution style contributed by repeated negative social experiences, which in turn drives withdrawal-based responses in social interaction. Children with ADHD are found to show positive illusory bias, making them less likely to consider the full impacts of their responses and outcomes, but more likely to engage in impulsive and overly ambitious responses with socially inappropriate behaviours. Also, the role of inattention and working memory deficits appears to be more relevant for cue misinterpretation in ADHD.

Step 3: Goal clarification

In step 3 of the social information-processing model, children need to clarify their goals for the social situations. Social goals can be relationship enhancing or building, or conversely, can also be relationship damaging or retaliatory.

Unfortunately, this current review has not identified studies specific to goal clarification in ASD and ADHD. Some inferences can be made from some indirect findings. Adolescents with ASD were found to rate withdrawal as a preferred response compared to typically developing peers[24]. This may reflect a tendency to adopt a non-social, withdrawal/avoidant goal orientation. Given their positive illusory bias, as described above, children with ADHD might be overly confident of their competency and adopted the overly ambitious goal of confronting their problems in social situations[13].

Steps 4 and 5: Response construction and decision

Findings on response construction and decision in adolescents with ASD found that the reduced breadth of social experiences and a higher proportion of harsh social experiences might be leading to limited availability of social problem-solving responses in their memory database. Consequently, adolescents with ASD were more likely to evaluate withdrawal responses as preferable in social scenarios and generate non-social withdrawal responses to avoid problems in social interaction[24]. These findings may be reflective of the real-life difficulties in initiating and responding to social situations experienced by individuals with ASD.

Children with ADHD tended to generate a lower proportion of positive responses and higher proportion of negative responses in social situations[13]. Children with ADHD had significantly higher rates of negative interactions with peers, including a higher rate of peer rejection. Thus, they were less likely to have positive responses in store in their memory database, but instead, they had many negative responses.

Step 6: Behavioural enactment

Behavioural enactment is the last step of the social information-processing model and is generally

conceptualized as the behavioural outcomes of the five previous cognitive steps upstream. Naturally, the culmination of deficits in those previous steps will lead to suboptimal behaviours being enacted, thus impairing social functioning in children with ASD or ADHD.

Children with ASD show deficits in observable social behaviours, including less social play and fewer social initiation, as well as poorer verbal and nonverbal social communication that reduces the effectiveness of their social interactions[1]. This absence of positive social behaviours in ASD can be seen as the result of upstream social cognitive and emotion recognition deficits, creating an inappropriate mental representation of the social situations combined with a tendency to choose and positively evaluate non-social withdrawal responses.

It has been suggested that children with ADHD may have adequate social knowledge but experience difficulty in enacting social behaviours appropriately[27,28]. This suggestion collaborates well with findings that children with ADHD are noted with relatively milder deficits in social perception/cognition compared to children with ASD[14,15]. Instead, they showed more inconsistency and variability in their social behaviours which appeared to be more strongly influenced by the core features of ADHD - inattention, hyperactivity, and impulsivity[12,19]. For example, children with ADHD were found to show elevated negative social behaviours such as barging in and poor sportsmanship, which were contributed by the core symptoms of hyperactivity/impulsivity. Due to inattentiveness, they were also found to demonstrate an absence of positive behaviours such as missing the pace and content of conversation[1]. One study demonstrated that social problems in ADHD primarily reflected inconsistent performance rather than the lack of knowledge and skills[2]. Using the social skill improvement system, a parent-rated measure of observable social behaviours, Aduen *et al*[2] found that children with ADHD exhibited more social performance problems than children without, while rates of social acquisition problems were relatively rare and idiosyncratic. These findings suggested that children with ADHD failed in fact to perform learned social skills consistently across settings. Another study also pointed to a social performance deficit in ADHD, as opposed to the lack of social knowledge and inherent social communication deficits seen in ASD[3]. For instance, while both ASD and ADHD groups exhibited significant social behavioural difficulties, deficits in children with ASD were characterized by significantly less adaptive and appropriate social behaviours, which was a reflection of a knowledge deficit, while children with ADHD were found to have more inappropriate assertiveness, a reflection of impulsivity. Table 1 summarizes the social information-processing deficits in ASD and ADHD.

COMMON OUTCOME, DIFFERENT PATHWAYS

Both ASD and ADHD have been well known for social impairment, exhibiting difficulties in relating with others. This is the common social outcome for the two disorders. However, the above review organized under the social information-processing model by Crick and Dodge[5] suggests different pathways traversing along the six steps of information-processing for children with ASD or ADHD to arrive at the common outcome.

Children with ASD start with an inefficiency in cue encoding and deficits in facial emotion recognition. They also exhibit a more severe deficit in social perception/cognition, which persists into adulthood without any sign of abatement. These encoding deficits, *e.g.*, well known as theory-of-mind deficits in the literature of ASD, consequently lead ASD children to generate a less accurate mental representation of the social situations in which they find themselves.

Regarding the interpretation of cues, children with ASD develop over time a negative, global attribution style in which they see themselves as helpless in effecting the social outcome. With this interpretation, they tend to opt for withdrawn and avoidance responses. There goes a vicious cycle in which these withdrawn/avoidance responses limit the breadth and positivity of the social experiences. These in turn reduce the availability or construction of positive social problem-solving responses to cope with the challenges in social situations. In the end, children with ASD, harbouring a withdrawn and avoidant response tendency, display less social play and fewer social initiation which thwart their social interaction.

Children with ADHD also start with a cue encoding deficit. This is followed by difficulties in social perception/cognition and facial emotion recognition. However, researchers speculate different origins of these encoding difficulties. For children with ASD, these encoding difficulties are cognitive deficits to social and emotion stimuli inherent to ASD, while for children with ADHD, they are by-products originating from interruption incurred by ADHD symptoms of inattention and hyperactivity/impulsivity. The latter suggestion is based on the observation that the encoding difficulties are random, non-specific, or variable across all valences, reflective of those momentary lapses of attention typical of ADHD. Children with ADHD thus display a performance deficit due to interruption by ADHD symptoms, but little acquisition problems on social knowledge. When the symptoms of ADHD are treated with stimulant medication, performance in social perception/cognition improves. Furthermore, an age-related improvement is also seen, in parallel with the age-related improvement in ADHD symptoms. All these point to an influential role of ADHD symptoms in hindering social information-processing. In the interpretation of social cues, children with ADHD also show a positive illusory bias,

which is of a different type from that of children with ASD. Such bias eventually leads to overly ambitious responses of confronting their problems in social situations. Once again, as in the case of children with ASD, children with ADHD are also locked in a vicious cycle in which inadequate social responses and negative social experiences are reinforcing each other and thus hinder the choice and construction of proper behaviour responses. Eventually, children with ADHD enact impulsive and inattentive behaviour, disrupting their social interaction with others.

In short, both disorders, ASD and ADHD, show social information-processing problems right from the very beginning and end with behaviour enactment that disrupts social interaction. However, as described above, the common social outcome is arrived at from different pathways that traverse along the six steps of social information-processing, invoking two cascading chains of deficits along the six steps. These eventually cumulate in suboptimal responses that hinder social relating, namely, withdrawn/avoidant responses from children with ASD, but intrusive/impulsive responses from children with ADHD. In brief, ASD does display inherent encoding deficits in social and emotion processing (*e.g.*, theory-of-mind deficits), while ADHD symptoms mar performance in social information-processing, despite a fairly intact pool of social knowledge acquired, *i.e.*, a social performance deficit rather than a knowledge deficit in ADHD.

CLINICAL IMPLICATIONS ON SOCIAL SKILL TRAINING FOR ASD AND ADHD

Social information-processing has been a focus of intervention to reduce aggressive and violent behaviours and increase prosocial behaviours in children[8]. The social skill training programs thus devised involve explicit teaching of social problem-solving steps using developmentally appropriate teaching strategies such as skill modelling, role play, and feedback. These programs are well studied with positive findings in relation to increased prosocial behaviours and reduced aggressive behaviours [8].

Fewer studies are conducted using specifically social information-processing as a model for social skill training with ASD and ADHD. One study that did so in a small group of five children with ASD found post-intervention improvement across multiple domains of social skills[29]. Another study with 27 children with ADHD also found improvement in social competency[30]. The scarcity and the small sample size of these studies mean that further intervention studies should be conducted to explore the usefulness of the social information-processing model in guiding the design and implementation of intervention programs for children with ASD or ADHD.

Proposed social information-processing treatment targets
The current review identifies in the social information-processing framework viable treatment targets for ASD and ADHD. At the early steps of social information-processing, children with ASD or ADHD both show reduced cue detection and encoding efficiency, specifically for detecting and recognizing emotion cues. Treatment that brings attention to and teaches the detection of relevant social cues (keeping attention on relevant and appropriate social and emotional cues, while screening out irrelevant cues) should be considered. Particularly for children with ASD, which show specific deficits in cue-encoding, strategies to increase their motivation to attend to and encode emotion-specific cues are more warranted, while for children with ADHD, maintaining overall attentiveness to social and emotion cues in social situations should be one overarching goal.

This review finds that children with ASD tend to show a more negative, depressive attributional style, while children with ADHD a positive illusory bias. Overall, both groups of children suffer from a biased interpretation of social cues contributing to an inaccurate mental representation of the social situations, and training should be targeted at improving the accuracy of interpretation, with consideration on the different biases that are more prevalent for the two disorders separately.

With respect to response generation and evaluation, children with ASD or ADHD both show a tendency to generate more negative responses, the former tending toward withdrawn/avoidant responses, while the latter toward more impulsive/intrusive responses. A common limiting factor for both groups of children is the absence of positive social experiences that allow these children to practice, evaluate, and receive feedback on generating and enacting positive social responses. Thus, the provision of positive social experiences should be incorporated in social skill training to expand the breadth of the social exposure of children with ASD or ADHD, in which more pro-social behaviours can be modelled/constructed, enacted, evaluated, and thus stored in the memory database for future use.

Finally, at the last step of behavioural enactment, the social difficulties of ASD and ADHD are of a social knowledge deficit *vs* a performance deficit. For children with ASD, the cumulative effects of deficits in cue encoding, interpretation, and response construction have produced a void in social knowledge and behaviour repertoire in coping with the demands of various social situations. Thus, knowledge-based social skill training to increase the pool of social knowledge and behaviours is essential to address the social impairment of children with ASD. For children with ADHD, the social impairment is of a performance deficit, caused by disruption arising from the inherent ADHD-related deficits in attention, working memory, and behavioural inhibition, as well as a generally lower IQ in

Table 1 Summary of social information-processing deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder

Social information processing steps	ASD	ADHD
Step 1: Encoding of social cues		
Cue encoding and detection	Children with ASD found to be less accurate in cue encoding in social situations	Children with ADHD found to encode fewer social cues, and this inefficiency non-specific across all valences, suggesting involvement of attention and working memory difficulties
Social perception/cognition	Children with ASD showing more severe social perception/cognition deficits than children with ADHD and typically developing children	A larger contributing role of neurocognitive factors in social perception/cognition deficits in ADHD, including lower intelligence and ADHD symptomatology
Facial emotional recognition	Children with ASD showing generalized deficits in facial emotion recognition across all emotions with difficulties persisting into adulthood, suggesting a failure to develop specialization and expertise in facial emotional processing	Children with ADHD showing weaker emotion recognition but with increased performance variability and random errors, suggesting contributory role of inattentiveness in failure to attend to the appropriate cues of affects
Step 2: Interpretation of cues	Children with ASD showing a negative, global attribution style contributed by repeated negative social experiences, driving in turn withdrawal-based responses in social interaction	Children with ADHD showing a positive illusory bias to engage in impulsive and overly ambitious responses; inattention and working memory deficits playing an important role in cue misinterpretation
Step 3: Goal clarification	Adopting a non-social, withdrawal/avoidant goal orientation	Adopting an overly ambitious goal of confronting problems in social situations
Steps 4 and 5: Response construction and decision	Adolescents with ASD evaluating withdrawal responses as preferable and generating such responses to avoid problems in social interaction; reduced breadth of positive social experiences limiting availability of appropriate social responses in their memory database	Children with ADHD generating a lower proportion of positive responses and a higher proportion of negative responses in social situations; higher rates of negative interactions with peers resulting in fewer positive responses stored in their memory database
Step 6: Behavioural enactment	Children with ASD showing a social knowledge deficit affecting the enactment of social responses, resulting in social responses consistently less adaptive and appropriate	Children with ADHD showing a performance deficit with increased inconsistency and variability in enactment of social behaviours, incurred by the core symptomatology of ADHD

ASD: Autism spectrum disorder; ADHD: Attention-deficit/hyperactivity disorder.

each step of social information-processing. Thus, there is a strong argument for the need to address attention and behavioural control in the management of social deficits in ADHD. Given the proven efficacy of stimulant medication on ADHD[31], such intervention should also produce beneficial effects on the social performance in children with ADHD. Indeed, there is evidence for this[14], but existing studies are few and some are inconclusive or inconsistent[32]. Behavioural training and scaffolding techniques that are also proven to manage ADHD symptoms[33] are the alternatives to be considered to deal with deficits in attention and working memory as well as behavioural disinhibition during social interaction. A recent meta-analytic review has indeed demonstrated the similar efficacy of both stimulant medication and behavioural treatment on the core ADHD symptoms[34]. Thus, future study should further examine if the social information-processing deficits of ADHD can be improved upon the alleviation of the core ADHD symptoms by existing efficacious medication and behavioural treatment.

CRITIQUES AND FUTURE DIRECTIONS

The social information-processing model is initially theorized and applied to explain aggressive behaviours in children independent of any specific clinical groups. As such, many assessment methods are specifically designed to elucidate social cognitive mechanisms underlying aggressive behaviours. For example, the SIPI which is designed specifically to assess social information-processing patterns of aggressive behaviours mainly includes negative social scenarios of peer provocation or peer rejection [6]. Furthermore, the vignettes and the interview-based method are not designed in consideration of the special needs of individuals with mentalistic functioning or language deficits such as those with ASD. As such, the interview-based SIPI and similar tools which rely on verbal comprehension and expression abilities to provide responses to the questions, and which require respondents to 'imagine' their involvement in hypothetical situations may prove difficult for children/youths with ASD and confound the assessment[24]. There is also concern on the limited ecological validity of these measures, using hypothetical situations; development and the use of more ecologically valid measures are thus suggested[13].

Despite the view that children with ADHD display a performance deficit in social functioning due to the impact of ADHD symptoms and a lower general IQ, not many studies have actually investigated or controlled the impact of these variables. Future studies should consider doing so, including the invest-

igation of whether the efficacious stimulant medication and behavioural treatments of ADHD symptoms can in turn also improve the social functioning of ADHD children, as hypothesized above.

A sizable subgroup of children with ADHD (25%-75%) have comorbid oppositional defiant disorder (ODD)[35], which is also well known to be associated with social functioning deficits. Previously, treatment of ODD has been challenging, relying mainly on behavioural treatment. However, a recent study has suggested potential beneficial medication treatment[36]. Once again, it is intriguing to examine if the successful alleviation of comorbid ODD in children with ADHD may also help their social functioning.

This review finds few studies that directly compare children with ASD against children with ADHD. This makes exact comparison of the deficits of the two clinical groups difficult. For those few studies which include both clinical groups, more exacting group differences are revealed. For example, Baribeau *et al*[15] found that children with ASD had the worst social perception/cognition deficits, while those of children with ADHD were milder. Furthermore, the social perception/cognition deficits of children with ADHD improved with age, while those of children with ASD did not[14]. Thus, more future studies should involve direct comparison between the two disorders in order to provide more exacting contrast to uncover the common and differentiating deficits contributing to their social impairment.

The social information-processing model has been applied successfully in a wide range of prevention and intervention programs to reduce aggression and promote prosocial behaviour[8]. Yet, few studies apply the social information-processing model to social skill training for ASD and ADHD. This review has made a series of suggestions above to identify viable targets for intervention. They should inform the design and implementation of potentially beneficial intervention programs for ASD and ADHD, respectively.

Finally, there is a recent concern regarding misdiagnosis of some medical conditions, *e.g.*, autoimmune encephalitis, for ASD[37]. Unfortunately, most existing literature in ASD does not address this disorder in the definition and recruitment of participants in their study so that we cannot estimate how far the conclusion of this current review is affected by the inclusion of participants with autoimmune encephalitis.

CONCLUSION

ASD and ADHD are both characterized by social impairment. This review applies the social information-processing model by Crick and Dodge[5] to define and compare the underlying deficits in the social cognitive mechanisms that contribute to the common outcome of social impairment in both disorders. It is found that both disorders show deficits at each step of social information-processing, but the nature and origins of the deficits may be different for the two disorders. In other words, the same outcome in social impairment may be arrived at by different pathways along the six steps of social information-processing. For ASD, there are difficulties in social/emotion cue detection, encoding, and interpretation, leading to a social knowledge/behaviour deficit that limits the availability and construction of behaviours to join or initiate social interaction. For ADHD, there is a performance deficit caused by disruption arising from ADHD symptoms of inattention and hyperactivity/impulsivity, leading to intrusive and impulsive behaviours that unsettle social interaction. Our conclusion essentially matches well with that of a recent review by Mikami *et al*[1], but our current review is framed under a coherent, well-developed model of social information-processing[5]. Social skill training that targets different loci of the social information-processing deficits of ASD and ADHD is well advised.

FOOTNOTES

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