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# Investigating the Use of a video-based Social Information Processing Interview Schedule (SIPIS) for Individuals with ASD subtypes

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## Abstract

**Introduction:** Although individuals with Autism Spectrum Disorders (ASD) and Attention Deficit/Hyperactivity Disorder (ADHD) share common social interaction deficits, there are specific differences in the quality of their social information processing.

**Objectives:** The purpose of this study was two-fold: (i) what are the measurement properties of the SIPIS, in measuring the construct of social information processing from the three aspects of social encoding, social empathy and social reasoning, in regard to its degree of fitness to the Rasch model? (ii) Can the SIPIS discriminate SIP performances between neurotypical controls, individuals with ASD and their subtypes?

**Methods:** Subjects with ASD and their subtypes were assessed through viewing social videos using the newly-developed Social Information Processing Interview Schedule (SIPIS). Rasch analysis was adopted to investigate the psychometric properties of the newly developed SIPIS including its discriminative validity.

**Results:** Findings of the Rasch analyses supported that the SIPIS contains assessment items that tap into the social encoding, social empathy, and social reasoning aspects of social information processing. Findings confirmed that both individuals with ASD and with ADHD manifest more difficulties in social information processing compared to the control group and that the social information processing deficits in individuals with ASD-only and comorbid ASD/ADHD tend to occur more at the cognitive level while in individuals with ADHD-only they occur more at the emotional perception level.

**Conclusion:** Our findings seem to support the parallel pathways of the bottom-up emotion perception-action coupling processes and the top-down meta-cognitive executive regulatory control. Future assessment and intervention can be further explored from the perspectives of social information processing.

**Keywords:** Autism spectrum disorders; Neurotypical controls; Hyperactivity; Social behaviors

## Introduction

Autism Spectrum Disorder (ASD) is characterized by impaired social communication and restricted repetitive behaviors, whereas Attention Deficit/Hyperactivity Disorder (ADHD) is characterized by severe inattention, hyperactivity and impulsivity [1]. A high rate of comorbidity of the two disorders has been consistently reported [2]. The rate of ADHD among individuals with ASD was found to be as high as 30-80% and the presence of ASD in individuals with ADHD as high as 20-50% [3]. Furthermore, the varying degrees of ADHD and ASD existing in between the spectrum of Autism disorders are attributed to the existence of many latent ASD subtypes [4]. In a study examining comorbid ASD in individuals with ADHD, except those in the ADHD-only group who exhibited primarily hyperactivity, almost all ADHD subgroups displayed some ASD symptoms [5].

While the typified deficits in social interaction characterize the diagnosis of ASD, the dysfunctional social behaviors are often accounted for by the impulsivity and hyperactivity of ADHD symptoms (1). Past research suggested that social interaction deficits are primarily related to an impairment of social information processing [6,7]. Social information processing (SIP) refers to the processes of how social cues are first interpreted, then consequently a social decision is made, and finally a social act results [8]. Lemerise and Arsenio [9] further elaborated SIP into six steps: (i) encoding of social cues, (ii) interpretation of social cues, (iii) clarification of goals, (iv) response formulation, (v) response decision, and (vi) behavior enactment.

Individuals with ASD have increasingly been regarded as having deficits in higher-level cognitive processing abilities while preserving enhanced or intact lower-level perceptual processing abilities [10,11]. The use of visual support strategies, as in the Pictorial Exchange Communication System (PECS) and Visual Activity Schedules, are generally known to be effective in helping individuals with ASD to follow implicit social rules in their daily living routine [12-14]. Through a systematic

representation of social-cognitive concepts by serial visual pictorial images, individuals with ASD are found to be more capable in regard to following an abstract time schedule such as transitioning between classes, or, performing daily social rules such as lining up. Such findings seem to imply that the visual processing of social information helps the cognitive processing in high-functioning individuals with ASD. Yet the reason behind the effectiveness of visual support strategies has not been studied in depth. Which specific social information processes are individuals with ASD particularly weak in? Although individuals with ASD and ADHD share common social interaction deficits, are there any differences in social information processing impairment across the various groups of ASD subtypes? These questions prompted this social information processing study using a video-based interview approach.

## Literature Review

Social interaction begins by the individual's orientation and attention to the relevant social cues from the environment. Once the social cues successfully register in the brain as a mental representation, the processes of social encoding and perception begin. This involves the interpretation of the social codes by the individual who draws references from their own existing memory store of acquired social rules and social schemas [8].

Following social encoding and interpretation, the individual formulates social response goals. Social empathy, the generation of an internal emotion response to the social event, is an essential component before any social response goals can be formulated. The external encoding and interpretation of social cues interplay with the orientation and intensity of the individual's internal emotion generation [15]. The emotional intensity being internally experienced by the individual merges with the intrinsic ability to regulate their own emotions. The resulting emotional status influences what and how social information is encoded and interpreted. Subsequently, it also influences the way the individual formulates social response plans.

Furthermore, neuro-scientific evidence has further identified the mediating role of internal emotion processing during social information processing [9]. In patients with damage to the ventromedial prefrontal cortex, that is, patients with intact motor and cognitive functions but impaired emotional functioning, no skin conductance responses were detected when disturbing images were presented. These patients were able to report the factual social content and the emotional connotation of the social stimuli, but they did not generate the same emotions internally themselves. Consequently, they exhibit poor social empathy in that they display difficulty in decision-making when expected social outcomes are not clear-cut but open-ended [16-18].

Apparently, internal social empathy involves conscious or external understanding of event-emotion links, mediates the subsequent social reasoning processes or response decision-making processes and eventually leads to adaptive behavioral flexibility [19]. Subsequently, a social response that is thought to

yield the best affordable outcomes is selected after weighing the external social expectations and the internal emotional needs. Representations of past social experiences consist of not just the cognitive memory but also the affective memory. The individual's emotion expectations can affect the formulation of social response options while the selection of social response can alter the individual's internal emotions. Thus, emotional perception of a social event may trigger different social response options. Likewise, retrieval of particular cognitive strategies can tap into the perception of various emotions [9].

During the final social response enactment stage, the individual needs to flexibly display emotions that address the specific social situation. Moreover, the individual's own internal emotion cues along with others' emotion cues provide an ongoing source of information regarding how the social encounter is proceeding, allowing the individual to make adjustments as the response enactment continues [20]. The emotion flexibility ability influences the individual's decision-making and problem-solving process during the ongoing social interaction event.

However, past studies showed weak to moderate correlations between emotion and cognitive functioning, suggesting that the two operate at different brain levels [21]. Decety and Meyer [22] attempted to explain the difference between the three social information processing aspects in terms of two different neural pathways that are running in parallel and interrelated, that is, a bottom-up process based on emotion perception-action coupling and potentially underpinned by mirror neuron systems and a top-down meta-cognitive executive regulatory control that modulates lower-emotion perception-action mechanisms. The metacognitive feedback, mediated by the individual's own intellectual competence, allows the individual to make a decision on whether to react or not react to the perceived affective states of others. Cognitive executive functioning takes place through shared neural circuits of the pre-frontal cortex, insula, limbic system, and fronto-parietal networks. The cognitive processes are mediated by specific interacting neural circuits responsible for self-awareness, mental flexibility, and emotion regulation [22]. Consequently, dysfunction along any part of these processes may lead to specific social information processing deficits depending on which aspect is disrupted [23]. Understanding in more depth the nature of social information processing through the lens of the two-way parallel neural pathways may prove significant in conceptualizing, identifying, and treating various subtypes of individuals with ASD who may have deficits with different social information processing foci [24].

## Study Design and Aim

In daily life, social interaction often happens instantly and subtle social information needs to be processed spontaneously. Dynamic social stimuli displayed in video formats can be better utilized in research to reflect different processing mechanisms than the static face photos used in past research [25]. The dynamic social video stimuli better reflect the real-life difficulties faced by individuals with ASD. Therefore, dynamic human stimuli presented in social videos were used in this study to investigate

if the ASD group can detect and perceive the subtleness of natural human expressions shown in daily social interaction. As no existing video-based measure using the mother tongue is available locally, the Social Information Processing Interview Schedule (SIPIS) was designed as a video-based interview measure using Cantonese for the local population in Hong Kong.

In this study, social information processing was primarily operationalized in three aspects, namely social encoding, social empathy and social reasoning [21]. Social encoding refers to the attention to relevant social information. In particular, the attention to the human emotional content during a reciprocal social interaction activates neural circuits and associated autonomic and somatic responses of the observer who forms a mental encoding of the person's emotional state. Social empathy refers to the ability to identify the feelings and desires of another person by taking that person's point of view [26]. Social reasoning refers to the ability to understand and interpret the impact of a person's emotional act on another person [23,27]. The three social information processing aspects are naturally interdependent and work together in leading to pro-social behaviors [21]. In this study, we aimed to investigate the social information processing of visual stimuli in subjects with ASD through their video-viewing of social episodes without audio inputs. Their recall of social information via social encoding, interpretation of others' emotions via social empathy, and problem-solving abilities in social situations via social reasoning were assessed using the newly developed Social Information Processing Interview Schedule (SIPIS).

Furthermore, we aimed to investigate the discriminative validity of the SIPIS by comparing the social information processing performance of neurotypical individuals and high-functioning individuals with different ASD subtypes using the SIPIS. Since it is possible that differences between ASD and neurotypical groups might be attributable to co-morbid ADHD, we tested whether the ASD-only group and the co-morbid ASD/ADHD groups differed from their neurotypical peers in terms of the aforementioned social information processing constructs, that is, social encoding, social empathy and social reasoning. The purpose of this study was two-fold:

What are the measurement properties of the SIPIS, in measuring the construct of social information processing from

the three aspects of social encoding, social empathy and social reasoning, in regard to its degree of fitness to the Rasch model [28].

Can the SIPIS discriminate the social information processing performances between TD controls, individuals with ASD and their subtypes?

## Methods

### Participants

Participants were local Asian Chinese-speakers and passed all screening criteria as explained below. The sample consisted of 60 individuals (42 boys, 18 girls) between the ages of 7 and 12 years ( $M=9.83$ ,  $SD=1.22$ ). Ethical approval from the university where the principal investigator is teaching and informed consent from the participants were obtained prior to the conduct of the study. The control group was recruited from 10 elementary schools from throughout the three Hong Kong districts via convenience sampling. An invitation letter cum permission form was sent to each parent of individuals in primary grade 3 through grade 6 in the participating schools (some of whom came with a diagnosis of ADHD-only). The ASD group was referred by local centers that provided intervention to individuals with ASD (some of whom had co-morbid ADHD). As convenience sampling was adopted, no attempt was made to match the groups with regard to gender and age.

Information about the sample is provided in **Table 1**. The control group consisted of 27 participants (age  $M=10.04$ ,  $SD=0.98$ ). The high-functioning ASD group consisted of 26 participants and was subdivided into two subtype groups, namely the ASD-only group of 11 participants (age  $M=9.58$ ,  $SD=1.80$ , ranging from 7.08 to 12.50) and the comorbid ASD-ADHD group of 15 participants (age  $M=9.51$ ,  $SD=1.05$ , ranging from 8.00 to 12.00). When recruiting the control group from the mainstream schools, seven individuals came with a diagnosis of ADHD (age  $M=10.14$ ,  $SD=1.35$ , ranging from 8.00 to 12.00), who were grouped into the ADHD-only group for cross-group comparison. There was no significant difference in age across groups ( $F=0.911$ ,  $p=0.442$ ).

**Table 1** Descriptive statistics of study.

Variable	All groups (N=60)	Control (n=27)	ADHD only (n=7)	ASD only (n=11)	ASD/ADHD comorbid (n=15)		
Gender (boys/girls)	42 / 18	14 / 13	42771	42802	15 / 0		
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p
Age (years)	9.83 (1.22)	10.04 (0.98)	10.14 (1.35)	9.58 (1.80)	9.51 (1.05)	0.91	0.442
Grade (level)	3.97 (1.34)	4.19 (1.18)	4.57 (1.13)	3.55 (1.92)	3.60 (1.12)	1.49	0.228
Raven	44.62 (6.56)	44.81 (6.75)	44.86 (5.76)	44.55 (5.99)	44.20 (7.51)	0.03	0.993

Note: Raven=Raven Standard Progressive Matrices' raw scores.

## Measures

The participants were classified primarily into the ASD and subtype groups and control group using two screening measures: (i) medical diagnostic report and (ii) Raven's Standard Progressive Matrices (Raven) [29]. Subsequently, each participant was further assessed by the newly developed measure, the Social Information Processing Interview Schedule (SIPIS).

**Raven's standard progressive matrices test (Raven):** The Raven test assesses the visual logical reasoning abilities of individuals from ages 5<sup>1/2</sup> to 16 [29]. In the current study, indexed raw scores relative to chronological age in an Asian population were converted to percentile scores that corresponded to five percentile ranks, giving an indication of how well the individual performed relative to same-age peers. More specifically, those who scored at the percentile rank of IV or V were classified as being at a below-average level, those at the rank of I at an above-average level, and those at the rank of II or III at an average level. **Table 1** shows the mean percentile ranks of the four study groups.

**Medical diagnostic report:** The high-functioning ASD group received a formal medical diagnosis of ASD and co-morbid diagnosis of ADHD from licensed medical consultants using DSM-5 criteria. These assessments were conducted as part of the usual diagnostic procedures at the ASD intervention center where recruitment took place.

**Development of the social information processing interview schedule (SIPIS):** The SIPIS was developed based on an idea that originated in the Social Problem-Solving Test (SPT) [30]. The SPT consists of 12 video vignettes with a structured interview. Each SPT video vignette consists of two parts, namely the presentation of the social problem and the problem-solving solutions. In our study, a new set of social video vignettes was developed for the SIPIS such that the content and language used suit the local context of Hong Kong. Only the presentation of the social problem component was included in the video content, leaving the solution component as open-ended questions for the participants to address during the interview after watching each video. An example is the protagonist received the same gift from his friends at his birthday party.

**Content review of the SIPIS videos:** The newly developed measure, the SIPIS, went through a two-phase content review. In the first phase, the initial 24 SIPIS video scripts written by the principal investigator were reviewed by a clinical psychologist and an experienced teacher based on the extent of their agreement on whether the social situation could evoke different perspectives of empathic functioning. As in the previous example of receiving the same birthday gift, the protagonist needs to make a decision on how to respond by taking the perspective of his friend who did not have prior knowledge of what gifts he would receive at his birthday party. As a result, 12 videos scripts were selected from the first content review and were produced by a professional film-making company. The videos produced then underwent the second phase of content review by two other experts, a social worker and a learning support teacher. Based on their feedback, seven video vignettes

were selected to constitute the final social video content of the SIPIS. The selection criteria included the length of the videos and the acting quality such as facial expressions of the characters.

During the assessment, the participant first viewed each one-minute SIPIS social video and was then interviewed using a set sequence of SIPIS interview questions. Prior to the start of each interview, the participant was asked to identify who the protagonists were in the social video just watched. The answers to the set of questions referring to the identified protagonist were recorded and later converted into verbatim text transcription. Based on the transcription data, the interviewer used a dichotomous rating scale to rate the subject's social information processing abilities in regard to the three social information processing aspects.

The first two questions were used as trials to make sure that the subject followed the interview schedule and referred to the same character in the video with a common name. Question Three (i.e., Q3) was related to the aspect of social encoding. A score of 1 was given when the subject was able to describe the major plot development of the video event. As there were seven videos and one question for assessing social encoding, there were altogether seven items for the seven videos in this domain.

Next, Questions Four and Five (i.e., Q4, Q5) were related to the aspect of social empathy. A score of 1 was given when the subject was able to state the thoughts of the character appropriately and another score was given when the subject was able to state the feeling of the character appropriately. As there were seven videos and two questions directed at each of the two main characters in the social video, there were altogether 28 items for the seven videos in this domain.

Lastly, Questions Six, Seven and Eight (i.e., Q6, Q7, Q8) were related to the aspect of social reasoning. A score of 1 was given when the subject was able to explain the feelings of the character by referring to his/her verbal or nonverbal behaviors; another score of 1 was given when the subject was able to make a judgment and when the subject could support their own judgments by referring to the impact of the first character's act on the second character respectively; and, a score of 1 was given when the subject was able to propose an alternative act and finally another score of 1 was given when the subject could explain how the alternative act can better impact on the characters. As there were seven videos and three questions directed at each of the two main characters in the social video, there were altogether 42 items for the seven videos in this domain.

So, during the pilot study stage, higher total scores indicated greater abilities of social information processing observed by the rater who went through the entire assessment procedures with the primary investigator who is a licensed occupational therapist. Their ratings on ten subjects in a pilot sample were compared and any discrepancies were discussed after each assessment until the inter-rater ratings reached 80% consistency. The data of the pilot study was excluded from this main study.

## Procedure

Once written permission was received by mail or email, the parents were contacted via phone and a one-hour assessment appointment was scheduled for each individual participant. If the individual was being prescribed medication for controlling their ADHD symptoms, the parents were advised not to administer the medication on the assessment day.

At the start of the assessment appointment, the parents had to provide us the individual's medical diagnostic report, prescription record of medication and relevant family history if any. The individuals were given a personal report of their own Raven report at the end of the assessment as an incentive for their participation.

## Data analysis

Rasch analysis was adopted to investigate the psychometric properties of the newly developed SIPIS. The Rasch model fit statistics measure the extent to which the observed data matches the predictions of the Rasch model. There are mainly two types of item fit statistics: the infit statistics that assess those items within the individuals' ability and the outfit statistics that assess those items which might be off-target, either too easy or difficult for the individuals [28]. The goodness-of-fit of each item is usually represented by the ratios of the observed scores versus the expected scores in terms of mean squared residuals (MnSq) and the standardized Z values (ZSTD). The mean square indices of greater than 1.4 or less than 0.6, or the absolute value of ZSTDs is greater than 2 or less than -2 have

frequently been established as criteria for misfit [31,32]. Rasch person/item reliability refers to the consistency of person/item ordering as measured by the scale. Person/item separation indices indicate the spread of the sample in terms of units of measurement error of the scale measures. Larger separation indices represent finer precision and higher reliability of the measure than smaller values [33]. Principal Component Analysis of residuals was carried out to investigate the dimensionality of the items. Furthermore, the SIPIS scores between the three subtype groups (i.e., ASD-only, comorbid ASD/ADHD and ADHD-only) and neurotypical group were also compared using ANOVA to investigate the contrast-group validity which assesses the discriminatory power of the instrument.

## Results

### Descriptive statistics

Descriptive data for all study variables is presented in **Table 1**. Of the 73 parents who had given consent to participate, five did not show up at their scheduled appointments and eight subjects were excluded based on parental reports of additional diagnoses apart from the diagnosis of ADHD or ASD (two individuals had specific learning disabilities and six had mild-grade intellectual disabilities). No participants had any visual problems or were in need of corrective eyeglasses. Analyses of variance (ANOVAs) were used to compare between-groups on age, grade and RSPM percentile rank; the groups did not differ significantly in regard to these variables.

**Table 2** Rasch item statistics on the SIPIS items.

Item	Logit	Error	Infit MnSQ	Infit ZTD	Outfit MnSq	Outfit ZTD	Point-measure correlation
<b>Social Encoding question of the seven videos</b>							
V2Q3	1.02	0.41	0.94	-0.2	1.02	0.18	0.62
V7Q3	0.13	0.53	1.19	0.72	1.21	0.56	0.33
V9Q3	0.11	0.41	1.16	0.79	1.15	0.47	0.53
V8Q3	-0.23	0.5	1.35	1.35	1.9	1.3	0.36
V5Q3	-0.54	0.5	1.52	1.75	1.64	1.03	0.29
V6Q3	-0.6	0.55	1.47	1.38	1.64	0.94	0.16
V4Q3	-1.37	0.58	0.9	-0.17	0.95	0.29	0.51
<b>Social Empathy questions of the seven videos</b>							
V2Q4a	1.67	0.4	1.25	1.27	1.43	1.16	0.5
V2Q4b	0.85	0.41	0.68	-1.59	0.58	-1.31	0.73
V8Q4b	0.47	0.47	0.58	-1.88	0.44	-1.37	0.75
V9Q4b	0.44	0.4	1.11	0.57	1.16	0.5	0.57
V7Q4b	0.13	0.53	1.15	0.57	1.15	0.45	0.36
V4Q4b	0.11	0.44	0.84	-0.63	0.77	-0.33	0.62

V7Q4a	-0.17	0.56	1.07	0.31	1.34	0.72	0.36
V4Q4a	-0.21	0.48	1.09	0.41	1.03	0.25	0.54
V2Q5a	-0.24	0.45	0.49	-2.56	0.31	-1.58	0.75
V2Q5b	-0.24	0.45	0.49	-2.56	0.31	-1.58	0.75
V9Q4a	-0.3	0.43	1.07	0.37	0.96	0.11	0.54
V6Q4a	-0.31	0.52	1.29	1.01	1.31	0.64	0.29
V6Q5b	-0.31	0.52	1.59	1.82	1.72	1.11	0.13
V9Q5b	-0.42	0.43	1.31	1.35	1.48	0.92	0.46
V4Q5a	-0.53	0.49	1.06	0.31	1.17	0.47	0.5
V4Q5b	-0.53	0.49	0.53	-1.99	0.3	-1.3	0.71
V5Q4b	-0.81	0.53	0.81	-0.59	0.52	-0.5	0.57
V5Q5b	-0.81	0.53	0.7	-1.02	0.42	-0.74	0.61
V6Q4b	-0.93	0.59	0.63	-1.09	0.3	-0.75	0.59
V5Q5a	-1.12	0.57	0.82	-0.43	0.47	-0.44	0.55
V7Q5a	-1.47	0.79	1.04	0.26	0.58	-0.01	0.32
V5Q4a	-1.48	0.62	1.06	0.28	1.33	0.63	0.39
V8Q5b	-1.77	0.65	1.12	0.42	1.3	0.66	0.27
V9Q5a	-1.82	0.56	1.04	0.24	0.49	-0.17	0.46
V6Q5a	-1.83	0.77	1.1	0.36	0.95	0.43	0.23
V8Q4a	-2.27	0.77	0.96	0.11	1.18	0.59	0.25
V7Q5b	-2.29	1.06	0.92	0.18	0.27	-0.28	0.31
V8Q5a	-3.05	1.04	0.79	0.03	0.18	-0.45	0.3
<b>Social Reasoning questions of the videos</b>							
V8Q7b	2.23	0.48	1.4	1.61	1.72	1.36	0.47
V4Q7a	2.15	0.41	2.09	4.63	2.51	1.97	0.16
V7Q7b	1.98	0.47	1.06	0.39	0.91	-0.15	0.5
V4Q8b	1.82	0.4	0.98	-0.06	1	0.18	0.59
V6Q8b	1.61	0.44	0.92	-0.41	0.78	-0.64	0.59
V7Q8b	1.55	0.46	0.75	-1.58	0.66	-1.18	0.63
V6Q7a	1.42	0.43	0.9	-0.51	0.76	-0.72	0.59
V2Q7a	1.35	0.4	0.84	-0.8	0.86	-0.31	0.67
V2Q8b	1.35	0.4	0.57	-2.49	0.43	-2.09	0.79
V8Q8a	1.35	0.46	1.35	1.4	1.19	0.6	0.52
V5Q8b	1.33	0.43	0.87	-0.62	0.77	-0.32	0.62
V7Q7a	1.33	0.46	0.84	-0.91	0.74	-0.87	0.58
V7Q8a	1.33	0.46	0.82	-1.02	0.73	-0.91	0.59
V9Q7a	1.24	0.39	1.1	0.53	0.98	0.09	0.61
V9Q8a	1.24	0.39	1.3	1.41	1.17	0.51	0.54
V9Q7b	1.24	0.39	0.96	-0.14	0.95	0.03	0.64

V4Q8a	1.18	0.4	0.81	-0.98	0.67	-0.68	0.66
V8Q8b	1.13	0.46	1	0.08	0.94	-0.03	0.63
V2Q6a	1.02	0.41	0.98	0	1.06	0.29	0.61
V8Q7a	0.91	0.47	1.75	2.57	1.75	1.69	0.34
V8Q6b	0.91	0.47	0.93	-0.19	1.04	0.22	0.63
V6Q7b	0.84	0.45	1.22	1.05	1.14	0.5	0.4
V2Q8a	0.68	0.41	0.91	-0.33	0.87	-0.25	0.63
V4Q7b	0.67	0.42	0.78	-1.05	0.65	-0.78	0.67
V6Q8a	0.63	0.45	0.79	-0.98	0.65	-0.86	0.62
V6Q6b	0.63	0.45	0.78	-1.02	0.64	-0.88	0.63
V5Q6a	0.56	0.44	1.11	0.56	0.97	0.08	0.52
V9Q8b	0.44	0.4	0.82	-0.85	0.6	-0.99	0.69
V2Q6b	0.37	0.43	0.4	-3.33	0.3	-2.23	0.81
V5Q7a	0.36	0.45	1.13	0.67	0.87	-0.14	0.51
V5Q7b	0.36	0.45	1.05	0.31	0.92	-0.02	0.53
V4Q6a	0.31	0.43	0.95	-0.15	0.84	-0.21	0.59
V2Q7b	0.15	0.43	0.8	-0.84	0.57	-1	0.67
V9Q6b	0.11	0.41	0.89	-0.45	0.62	-0.79	0.65
V5Q6b	-0.06	0.47	0.83	-0.68	0.66	-0.54	0.6
V7Q6a	-0.17	0.56	0.63	-1.18	0.46	-0.97	0.6
V7Q6b	-0.17	0.56	0.91	-0.16	0.65	-0.5	0.49
V9Q6a	-0.23	0.42	1.1	0.52	0.87	-0.09	0.55
V4Q6b	-0.3	0.47	0.47	-2.5	0.29	-1.54	0.74
V6Q6a	-0.31	0.52	0.97	0	0.79	-0.11	0.46
V5Q8a	-0.54	0.5	1.17	0.69	1.4	0.75	0.42
V8Q6a	-1.05	0.55	1.08	0.37	1.06	0.4	0.38

MnSQ - mean squared residuals; ZTD – standardized Z values; SIPIS – Social information processing interview schedule.

V2, V4, V5, V6, V7, V8 and V9 are codes representing each of the seven SIPIS videos. The dichotomously rated (Yes / No) SIPIS items include.

Q3 - What had happened in the video? (Score of 1 is given when the subject is able to describe the major plot development of the video event);

Q4 a/b - What was (Character a/b) thinking when he/she did (that)? (Score of 1 is given when the subject is able to state the thoughts of the character appropriately).

Q5 a/b - How did (Character a/b) feel in this situation? (Score of 1 is given when the subject is able to state the feeling of the character appropriately);

Q6 a/b – How do you know (Character a/b) felt that way? (Score of 1 is given when the subject is able to explain the feelings of the character by referring to his/her verbal or nonverbal behaviors).

Q7 a/b – Do you think (Character a/b) act appropriately? Why? (Score of 1 is given when the subject is able to support own judgments by referring to the impact of Character a's act on Character b appropriately).

Q8 a/b – If you were (Character a/b), would you have done something differently to make everyone feel better? Why? (Score of 1 is given when the subject is able to propose an alternative act which yields better impact on the Characters).

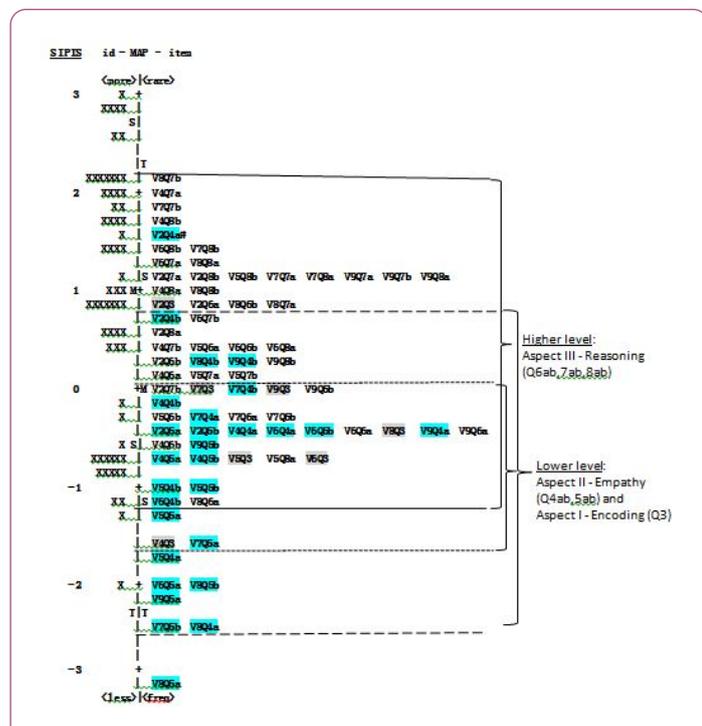
## Rasch analysis of the SIPIS

The SIPIS contains a total of 91 items from the seven videos, with each video contributing 13 items. Rasch analysis was conducted on 77 items as responded to by 80 persons as the first two prompting questions with a total of 14 items were for

trial run. The results showed that almost all items had Rasch item fit statistics between 0.5 and 1.5 and item difficulties ranged from -3.05 to +2.23 (**Table 2**). The Principal Component Analysis of Rasch residuals showed that the variance explained by the Rasch measure was 39.5%, and the eigenvalue of the first contrast in the residuals was 5.1, which is greater than 2.0, the

recommended criterion value for establishing unidimensionality [34], suggesting that the SIPIS probably contains items that tap into the different aspects of social information processing.

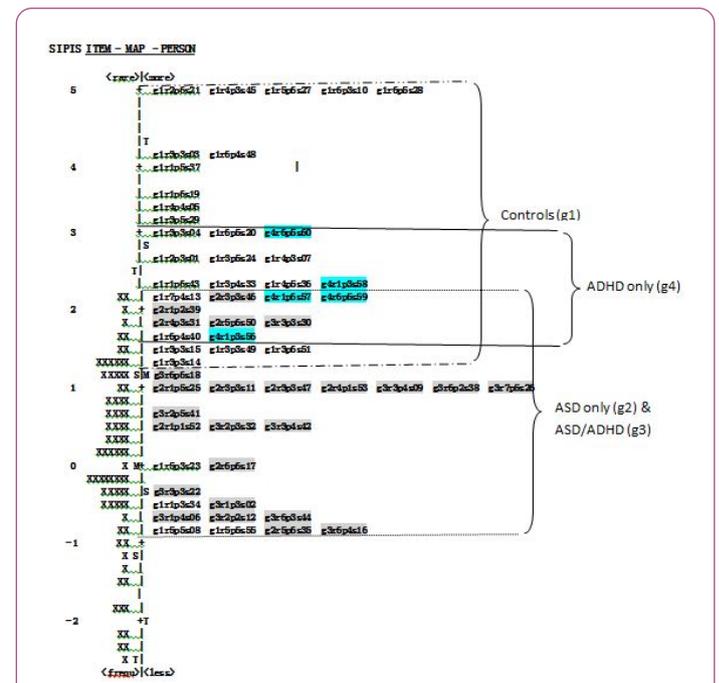
The Rasch analysis also found that the measure had a Rasch item reliability of 0.82 indicative of good item reliability. As seen in the Rasch item difficulty distribution map (Figure 1), the item difficulty ranged from -3.05 logits (i.e., where the least difficult SIPIS items are situated) to +2.23 logits (i.e., where the most difficult SIPIS items are situated). There was an item separation index of 2.04, suggesting that the items could be separated into about two difficulty levels according to the responses by students. As seen in Figure 1, the lower item difficulty level consisted of the two aspects of social encoding (i.e., logits ranged from -1.37 to +1.02) and social empathy (i.e., logits ranged from -3.05 to +1.67). The higher item difficulty level consisted of the aspect of social reasoning (i.e., logits ranged from -1.05 to +2.23).



**Figure 1** SIPIS item difficulty distribution map. V4Q7a - an example of student code in transparent for Social Reasoning questions (Q6, Q7, Q8); V6Q5b - an example of student code in blue for Social Empathy questions (Q4, Q5); V7Q3 - an example of student code in grey for Social encoding questions (Q3). V4 - video number; Q7 - question number; a or b - protagonist. The higher the item code is located on the map, the more difficult the item is. X represents a person on the SIPIS; M=Mean; S=1 SD; T=2 SD. SIPIS – Social information processing interview schedule.

As seen in the Rasch person ability distribution map (Figure 2), the performance range of all the participants extended from -1.11 logits (i.e., those who scored the lowest on the SIPIS) to +5.22 logits (i.e., those who scored the highest on the SIPIS). The mean person or participant ability was located at +1.02 logits (SD=1.78). The summary statistics showed a very high person

reliability coefficient of 0.89. The person separation index was 2.85, which means that the samples of students could be divided into almost three groups according to their level of the response performance being measured. In this study, we could see that the performance data of the four groups of participants in our study, namely, (i) control, (ii) ASD-only, (iii) ASD/ADHD comorbid, and (iv) ADHD-only, when calibrated against the SIPIS item difficulty levels on the same item-person map, could be divided distinctively into three levels. To be specific, as seen in Figure 2, at the first level, the control group (in transparently coded boxes) performed at the highest level with person ability ranging from -0.59 to +5.22 logits and the highest performance at 2 standard deviations (SD) above the mean ability, which was set at +1.02 logits. At the second level, the ADHD-only group performed in the range from +1.74 to +2.88 logits with the highest performance at around 1 SD above the mean ability, overlapping at the lower range of person ability with those of the control group. The third level consisted of the ASD-only or ASD/ADHD group, which performed in the range of -1.11 to +2.11 logits.



**Figure 2** Person ability distribution map on the SIPIS. 'g1r6p5s28' - an example of student code in transparent box for the control group; 'g2r3p3s46' - an example of student code in grey box for the ASD-only and ASD/ADHD groups; 'g4r1p3s58' - an example of student code in blue box for ADHD-only group. g1 - control group; g2 – group 2 for ASD; g3- group 3 for comorbid ASD/ADHD; g4- group 4 for ADHD only. r1/ r2/ r3/ r4/ r5/ r6 refers to the student's percentile rank on the RSPM with r1being the highest and above-average score and the rest being at the average level. 's03' is an example student ID number. The higher the student code is on the map, the higher the student's SIPIS performance. X represents an item on the SIPIS; M=Mean; S=1 SD; T=2 SD.

### Discriminative validity of the SIPIS

In an attempt to investigate the discriminatory power of the SIPIS, a one-way between subjects ANOVA was conducted across the four groups. Findings indicated that there was a significant group difference in all subscales of SIPIS across the four subtype groups (**Table 3**).

For the subscale of social encoding, there was significant difference for the four groups [ $F(3, 56)=5.30, p=0.003$ ]. Post hoc

comparisons using the Tukey's HSD test indicated that the mean score for the control group ( $M=2.78, SD=0.64$ ) was significantly higher than for the ASD/ADHD Comorbid group ( $M=1.60, SD=1.24$ ). For the subscale of social empathy, there was significant difference for the four groups [ $F(3, 56)=2.86, p=0.045$ ]. Post hoc comparisons using Tukey's HSD test indicated that the mean score for the control group ( $M=5.59, SD=1.01$ ) was significantly higher than for the ASD/ADHD Comorbid group ( $M=4.27, SD=1.91$ ).

**Table 3** Between-groups comparison using the Social Information Processing Interview Schedule (SIPIS).

SIPIS Variable	All groups (N=60)	Control (n=27)	ADHD only (n=7)	ASD only (n=11)	ASD/ADHD comorbid (n=15)	F	p
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)		
(Motor Empathy) Social Encoding / Attention	2.27 (1.07)	2.78 (0.64)	1.86 (1.46)	2.18 (0.87)	1.60 (1.24)	5.3	0.003 <sup>b</sup>
(Affective Empathy) Emotion identification	5.10 (1.49)	5.59 (1.01)	4.86 (1.95)	5.18 (1.17)	4.27 (1.91)	2.86	0.045 <sup>b</sup>
(Cognitive empathy) Social reasoning	16.03 (6.22)	20.04 (4.16)	16.00 (4.90)	14.09 (5.26)	10.27 (5.61)	13.83	0.000 <sup>a,b</sup>
Overall Empathic functioning	23.42 (8.03)	28.63 (4.98)	21.86 (7.47)	21.18 (5.81)	16.40 (8.22)	10.81	0.000 <sup>a,b</sup>

<sup>a</sup>denotes significant differences between Control and ASD only.

<sup>b</sup>denotes significant differences between Control and ASD/ADHD comorbid.

For the subscale of social reasoning, there was significant difference for the four groups [ $F(3, 56)=13.83, p=0.000$ ]. Post hoc comparisons using Tukey's HSD test indicated that the mean score for the control group ( $M=20.04, SD=4.16$ ) was significantly higher than for the ASD group ( $M=14.09, SD=5.26$ ) and ASD/ADHD Comorbid group ( $M=10.27, SD=5.61$ ). Regarding the overall SIPIS scores across the four groups, there was significant difference across the four groups [ $F(3, 56)=10.81, p=0.000$ ]. Post hoc comparisons using Tukey's HSD test indicated that the mean score for the control group ( $M=28.63, SD=4.98$ ) was significantly higher than for the ASD group ( $M=21.18, SD=5.81$ ) and ASD/ADHD Comorbid group ( $M=16.40, SD=8.22$ ). In summary, the overall findings showed that the control group scored significantly higher than the ASD/ADHD Comorbid group in all four SIPIS subscales, namely, Social Encoding, Social Empathy, Social Reasoning and overall SIPIS scores. The control group also scored higher than the ASD group in the subscale of social reasoning and the overall SIPIS scores.

Finally, the effect size associated with the six significant group differences shown in **Table 3** ranged from 0.87 to 2.00, which are considered to be large effect sizes [36]. However, it should be noted that among the four subject groups under study, some groups were smaller than the others (e.g., the ADHD group had seven individuals only). This might weaken the actual power achieved.

### Discussion

In regard to the first objective, results of the Rasch analyses supported that the SIPIS contains items that tap into the three SIPIS aspects of social information processing in the aspects of social encoding, social empathy, and social reasoning for individuals. As seen in **Figure 1**, the SIPIS item map showed three emerging levels of item difficulty. Each level tends to progress in a hierarchical way, with items of social encoding (i.e., aspect 1) being the least difficult at the bottom of the item-difficulty map, followed by social empathy (i.e., aspect 2) related items in between, then the items of social reasoning (i.e., aspect 3) being the most difficult at the top of the map (**Figure 1**). This finding suggests that social reasoning items demand more cognitive processing than those of social encoding and social empathy, which seem to be at a prerequisite level lower than the cognitive level. This finding seems to support the parallel pathways as proposed by [22]. That is, social encoding and empathy belong to the bottom-up emotion perception-action coupling processes whereas social reasoning processes occur at the top-down meta-cognitive executive regulatory control that modulates lower emotion perception-action mechanisms.

For the second objective, as seen in **Figure 2**, current findings confirmed that both individuals with ASD and with ADHD manifest difficulties in social information processing compared to the control group (i.e., group 1) but the results of the Rasch person-ability analysis indicate that the social information processing deficits in individuals with ASD-only (i.e., group 2)

and comorbid ASD/ADHD (i.e., group 3) tend to occur more at the cognitive level while for individuals with ADHD-only (i.e., group 4) they tend to occur more at the emotional perception level. This is consistent with the hypotheses put forward by Dziobek et al. [37] which stated that the social information processing deficits of different ASD subgroups appear to be qualitatively different. Individuals in the ASD-only and comorbid ASD/ADHD groups scored lower and performed significantly less successfully in higher-level cognitive social reasoning items when compared to the ADHD-only group and the controls. They showed more difficulties in social judgment and in offering alternative social responses to remediate a social situation.

In the open-ended question about judging a social act they had observed from the characters, their answers seldom referred to the emotions perceived from the characters' facial expressions and the intentions behind the social act. Furthermore, they tended to use categorical social rules to determine the appropriateness of the social act. They tended to give binary answers, such as 'happy versus unhappy' when asked about the character's emotion, or, 'ought versus ought-not' when asked to judge the social act. For example, "the boy should not pat his friend's shoulder because one should not hit others" without acknowledging that the boy was actually trying to say hello in video 4. Finally, in their verbal responses to the question about suggesting better alternatives, they tended to describe what they literally saw, such as "Person A pat person B's shoulder and then they fought", and had difficulty in judging the social problems and hence failed to formulate appropriate social action strategies to remediate the social situations.

In our study, individuals with ASD-only were able to encode the social stimuli but showed difficulty in describing the emotional states of others and interpreting the impact of social acts on others' emotions, thereby scoring lower on the social empathy items as well as the social reasoning items. Our findings agree with previous studies on individuals with high-functioning ASD, who did not show evidence of gaze avoidance compared to their control but were found to have less accuracy in the recognition of emotions and mental states especially in the identification of complex mental states, which requires more cognitive understanding of the other person's intentions [37].

On the other hand, individuals with ADHD-only displayed more difficulty in answering accurately the social encoding questions and therefore performed less successfully in the lower emotion-perceptual level of social information processing. In questions about recalling the already-viewed social events, they tended to omit some major social plot-lines and replaced their omissions by inventing non-existent story plot-lines of their own. Subsequently, the deficits in social encoding would make them less able to take others' emotions into consideration and perform more poorly in social empathy items. Such results are in congruence with past studies which found that inattention is a significant contributor to poor social perception [38].

Individuals with ADHD-only are often thought to have different arousal thresholds as compared to their neurotypical peers. They may either be under-aroused, showing lethargy, or over-aroused, showing impulsivity [39]. Once emotionally aroused to perform in social interaction, individuals with ADHD

often find it challenging to sustain and regulate their emotions throughout the subsequent social information processing stages [40]. The ADHD symptoms manifested as high emotionality and poor emotion regulation will distort their social encoding which subsequently impedes their social empathy and judgment in social information processing. Lastly, individuals with co-morbid ASD and ADHD show compound deficits in all social information processing, including social encoding, empathy and reasoning.

## Limitations of the Study

The overall small sample size might have limited our ability to detect differences between groups in our study. The significant effect sizes of the difference between the control and ASD groups were medium, ranging from 0.40 to 0.69 with a mean of 0.50, but the small sample might have limited the ability to identify smaller effects as significant [41]. The sample might have been larger and more diverse, especially for validating a newly developed measuring instrument.

Furthermore, the relative small size of the overall sample limited us from verifying the construct equivalence between subgroups. However, age was not addressed as a covariate in our study as the diversity in ages (i.e., ranged from 7 to 12 years of age) would make the number of individuals in each group much too small, especially for the clinical groups. This made the group comparison analyses harder to interpret given that age was not controlled. In addition, the lack of gender balance in each group also made generalizations to populations under study highly questionable.

Moreover, this research was carried out in a Chinese population. Its validity and reliability when used in other countries or in other ethnic groups will need to be further explored. Last but not least, in our study, we attempted to match visual IQ using the Raven ranking scores. However, for verbal IQ, only clinical observation was used with no standard testing support. As long as the participant could respond in full sentences verbally in the interview and sat through the photo viewing, they were included in the study. As a result, no verbal IQ scores were available for between-group comparison in the SIPIS assessment. In future research, participants' verbal IQ scores should also be obtained to enable a more comprehensive analysis of the confounding integrated effect of visual and verbal IQ on an individual's performance regarding social empathy and social reasoning. In addition, the age range of the participants can be expanded to including those of adolescents.

## Implications for Practice

The evidence provided by the three aspects of the SIPIS has shed light on our intervention strategies for different ASD subtypes. First, developing an intervention under the parallel pathway framework will lead us to develop a social information processing intervention with two main foci: (i) emotion perceptual training on the awareness and regulation of both internal and external emotional influences on social behaviors, and, (ii) meta-cognitive training on social judgment and problem-solving strategies. For individuals with ADHD whose deficits are found to be more emotionally driven, emotion-

manipulation training may be more effective than cognitive-behavioral training that focuses on knowledge acquisition of pro-social skills [9]. In contrast, individuals with ASD may benefit from meta-cognitive perspective-taking training as well to enhance their social empathy reasoning abilities.

Past intervention approaches have focused more on changing an individual's cognitive knowledge structures [42] but shaping an individual's emotion content or knowledge structures is equally important. Emotion manipulation approaches are founded on the premise that internal emotions within a person and external in others interplay to mutually regulate social information processing in social encounters. Manipulating both internal and external emotional cues in social situational stimuli therefore play a major role in mediating social information processing [9].

## Conclusion

This study adds scientific data from the Chinese population regarding the social information processing performance of social video stimuli by high-functioning individuals with ASD. Although individuals with ASD and ADHD share common social interaction deficits, there are specific differences in the quality of their social information processing. Future assessment and intervention can further explore the aspects of social encoding, empathy and reasoning, using the social information processing perspectives.

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