# The Ability of Hong Kong Children with Attention-deficit Hyperactivity Disorder to Recognise Facial Emotion

# 香港過度活躍症兒童的面部情感認知能力

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## Abstract

**Objectives:** To evaluate the facial emotion recognition ability in local children with attention-deficit hyperactivity disorder (ADHD) and the effect of inattention and impulsivity on such ability.
**Participants and Methods:** Eight-seven Chinese children (45 controls and 42 with ADHD) of primary 1 to 3 were recruited. They were matched for age, sex, intelligence, and family income. The subjects were shown facial emotion pictures developed by Matsumoto and Ekman (1998) together with emotional story vignettes. Conners' Continuous Performance Test II was used to evaluate the attention / impulsivity level of the subjects.
**Results:** The difference in performance in facial emotion recognition between the 2 groups was not statistically significant. There was also no significant correlation between the accuracy of facial emotion recognition and the inattention / impulsivity level. Intelligence level correlated significantly with the facial emotion recognition ability.
**Conclusions:** The ability to recognise facial emotion is affected by multiple factors. A single diagnostic label is unlikely to be fully predictive. Further research on the influence of co-morbidities and presence of different ADHD subtypes should be considered.

***Key words:*** *Asian continental ancestry group; Attention deficit disorder with hyperactivity; Facial expression*

## 摘要

**目的：**評估過度活躍症（ADHD）兒童的面部情感認知能力，以及探討分心和行為衝動對這種能力的影響。
**參與者與方法：**87名（45名控制組和42名ADHD組）就讀小一至小三的華藉兒童，在年齡、性別、智力和家庭收入皆合乎資格的情況下參與研究，進行由Matsumoto and Ekman（1998）開發的面部情感圖片以及其他情感故事小插圖的閱讀測試，並以Conners持續表現測試II評估ADHD集中力和行為衝動水平。
**結果：**在面部情感認知表現方面，兩組之間並無顯著分別；面部情感認知的準確性與分心／行為衝動水平間也無顯著相關性，但智力水平與面部情感認知則有顯著關係。
**結論：**面部情感的認知能力可受多種因素影響。單一的診斷標籤不可能作充分預測。進一步研究相關疾病的影響和不同的ADHD子型是需要的。

***關鍵詞：****亞洲大陸血統群、過度活躍症、面部表情*

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## Introduction

Attention-deficit hyperactivity disorder (ADHD) is one of the most frequently diagnosed psychiatric ailments in school-aged children. In recent years, research in ADHD has generated considerable advances in understanding the disorder. Increased awareness of the condition among professionals and the lay public has contributed to an increase in the numbers of such children presenting to psychiatric services. Based on criteria from the 4th edition of the Diagnostic and Statistical Manual of Mental

Disorders (DSM-IV)[1] in the United States, its prevalence is estimated to be 5% to 15%.[2,3] A Spanish study of a non-referred sample of 10-year-old children found a 4.9% prevalence of clinically significant ADHD based on semi-structured clinical interviews with parents.[4] According to the National Ambulatory Medical Care Survey, the percentage of office-based visits resulting in a diagnosis of ADHD increased from 1.1% in 1990 to 2.8% in 1995.[5] It was suggested that the worldwide prevalence of ADHD is between 3% and 5%.[5] In Hong Kong, its prevalence in Chinese schoolboys was estimated to be 8.9% (based on DSM III-R criteria).[6]

Inattention, impulsivity, and hyperactivity are hallmark features of the disorder. Significant impairment in social functioning is experienced by children with ADHD.[7] In view of the social deficit they experience, misinterpretation or failure to identify vital social cues in the environment may contribute significantly to the dysfunction,[8] as these are important components of social information processing. Among the social cues encountered in our normal daily life, facial expressions are important for communication. Previous studies have investigated deficits in social cue processing and facial emotion recognition by ADHD children. Singh et al[9] studied 50 children and adolescents with ADHD using DSM III-R criteria, and reported that the accuracy of facial emotion recognition of the studied children was 15% lower than that of a sample from the general population.

When previous research on emotion recognition ability or social cues encoding by ADHD children was evaluated,[10-15] potential confounding factors like socio-economic status, intelligence and gender did not seem to have been fully considered. The ADHD group usually had lower intelligence and male predominance. This study therefore aimed to evaluate facial emotion recognition ability in Chinese children with ADHD with a matched sample of normal children in Hong Kong, as well as any possible correlation of such ability and the degree of attention and impulsivity in the ADHD children.

## Methods

### *Inclusion Criteria and Demographic Data*

The ADHD cases were recruited from the outpatient clinic of a local psychiatric department; the controls were recruited from two local mainstream primary schools in Hong Kong. Inclusion criteria for the subjects were: (1) aged 6 to 9 years; (2) primary 1 to 3 students; and (3) no history of epilepsy or significant head injury (resulting in hospitalisation). Cases of ADHD with a known history of autistic spectrum disorder and mental retardation were not recruited. Written information describing the purpose of the study and procedures involved was given to the parents or main carers (e.g. grandparents) of potential subjects. Written informed consent was obtained. Relevant demographic information was collected by a questionnaire completed by the parents or main carers.

Because of the similarity in methodology and targeted sample, the results of Singh et al's study[9] were used as a reference for sample size calculation. The difference between the ADHD subjects and normal controls was estimated to be 15%. Power was set to be 80%. The calculated sample size was 32 subjects in each arm.

### *Screening of Intellectual Ability*

All subjects completed the Raven Progressive Matrices Test,[16,17] a non-verbal test of reasoning ability based on figural test stimuli. The test measures the ability to form comparisons, to reason by analogy, and to organise partial perceptions into systematically related wholes. In the current study, Standard Progressive Matrices (designed primarily for persons aged 6 to 17 years) were used. They contain 60 items presented in 5 sets, with 12 items per set. The raw scores of the progressive matrices test can be converted into percentile ranks and standardised scores according to the age of the tested subjects, and provide a measure of intelligence based on figural reasoning ability. The test has adequate concurrent validity as established by correlations with other intelligence and achievement tests.[18] In our study, subjects with standardised scores below 80 were excluded.

### *Assessment for Subjects with Attention-deficit Hyperactivity Disorder*

The Chinese version of a computerised structured interview, the Diagnostic Interview Schedule for Children, version IV (DISC-IV; original New York State Psychiatric Institute version, Chinese translation)[19] was completed by the parents or main carers of the recruited subjects in order to verify the clinical diagnosis of ADHD. The DISC-IV generates a diagnosis of ADHD according to DSM-IV criteria. Subjects showing negative result for the diagnosis were excluded.

Computerised Conners' Continuous Performance Test II, version 5 (CPT-II) was used to assess the level of attention and impulsivity of ADHD subjects. The CPT-II is an established neuropsychological tool for assessment of ADHD children aged 6 years and older, which takes 14 minutes to complete. Respondents are required to press the space bar on the keyboard of a computer whenever any letter except the target letter "X" appears on the screen. After completion of the test, variables are generated reflecting the level of inattention and impulsivity of those tested. All subjects performed the test devoid of any psychostimulant intake for at least 48 hours, and in the presence of the investigator at the day hospital of the psychiatric department.

### *Assessment for Control Subjects*

Subjects with any history of attendance at mental health or psychological services were excluded from the controls.

The Strengths and Weaknesses of ADHD symptoms and Normal behaviour (SWAN) rating scale, a 7-point scale developed by Swanson et al[20] for screening of ADHD symptoms was completed by the parents or main carers of potential controls to exclude any possibility of potential or undiagnosed ADHD. The SWAN measures both the strength and weakness in the symptom profile using a percentile cut-off. As suggested by Swanson et al,[20] 2.00 was adopted as the reference cut-off point. Control subjects scoring higher than 2.00 were excluded.

### *Facial Emotion Recognition Test*

All those recruited (ADHD subjects and controls) were tested for the accuracy of facial emotion recognition.

Coloured photographs of facial expressions (facial stimuli) of Asians were used since there is evidence of within-group advantage, i.e. emotional communication may be more accurate when the person expressing the emotion and the one perceiving the facial expression are both from the same cultural background.[21,22] Two sets of Japanese photographs were taken from the Matsumoto and Ekman's[23] "Japanese and Caucasian Facial Expressions of Emotion" (JACFEE) representing the 6 primary emotions of happiness, sadness, anger, fear, disgust, and surprise. This set of facial stimuli has been used in a number of cross-cultural and developmental studies, and includes 12 photographs (6 of each sex) based on their highest degree of accuracy as reported by Matsumoto and Ekman.[23]

Six vignettes describing the context of the emotional states of the 6 basic emotions were used to aid the subjects in identifying the relevant facial stimuli. The vignettes were already translated and used in a local study investigating development of facial emotion recognition in 4- to 13-year-old children.[10] The original vignettes were designed and validated by Ribordy et al,[24] and each carried an emotion label to prevent misinterpretation of the stories.

The emotion recognition task was individually administered to the subjects by the investigator. For ADHD subjects, it was conducted in an interview room in our psychiatric unit, and for controls in a classroom at school. Prior to presenting the vignettes to each child, the researcher read the following instructions: "We are going to play a little game. I shall read to you a story about Siu Ming. After that I shall show you 6 photographs. I want you to choose the photo that goes best with Siu Ming's feeling."

For each vignette presentation, the order of the 6 emotion photographs was randomly displayed on the same page. Each child was given 12 trials to familiarise themselves with the test. Then the 6 emotion vignettes were presented twice for matching both the male and female photographs for the 6 emotions. The order of vignette presentation was also randomised. Each child had to go through this set of 24 emotion vignettes. After each vignette was read, the emotion label would also be read. The children were then asked to select the relevant emotion photograph out of those shown to them. All subjects completed the test within 15 minutes.

### *Recruitment Procedure*

Fifty-seven subjects with a clinical diagnosis of ADHD were invited during the follow-up sessions in the out-patient clinic. Informed consent was signed and the demographic questionnaire was completed by the parent or carer. Consenting parents or carers performed the DISC-IV to verify the clinical diagnosis of ADHD; 2 subjects were excluded because the results of the test were negative. Then the recruited children completed the Facial Emotion Recognition Test, CPT-II, and Raven Progressive Matrices Test within 1.5 hours. All subjects completed the CPT-II and Facial Emotion Recognition Test on the same day. Another 8 were excluded: 2 because of failure to engage in the testing procedure, and 6 for not being available to perform the tests. After completion of all the tests, 5 were excluded because they scored less than 80 on the Raven Standard Progressive Matrices Test. Thus, 42 ADHD children were included in the final analysis.

For the control group, 132 students were recruited on a voluntary basis with the guidance of teachers at the respective primary schools. Informed consent forms were signed by their parents or main carers, at which point demographic information and the SWAN rating scale scores were also obtained. The demographic profile was screened and matched with that of the ADHD children in order to minimise the effect of potential confounding factors (age, sex, form of school, and family income). After this exercise, 54 students were selected; 2 of whom had SWAN rating scale scores above the cut-off point, 1 gave a history of epilepsy, and 1 had attended mental health services. These 4 subjects were therefore excluded from the study. One at a time, the remaining 50 students were then recruited to perform the Raven Standard Progressive Matrices Test and the Facial Emotion Recognition Test with the investigator on a normal school day. Three subjects with low scores in Raven Standard Progressive Matrices Test, and 2 who were uncooperative were excluded.

## Results

### *Demographic Information*

In all, 42 ADHD and 45 control subjects were included in the final analysis; 91% of the ADHD subjects and 78% of the controls were boys. The mean age of both groups was 8 years. More fathers of the controls had had tertiary education; 6 (14%) in the ADHD group and 16 (36%) among controls. There was no apparent difference between the groups for the education level of the mothers. The majority of the subjects in both groups had family incomes ranging from HK$10,001 to 30,000: 22 (51%) in the ADHD group and 19 (42%) in the controls. Differences between the 2 groups in terms of demographic profiles were not statistically significant (Table 1).

### *Raven Standard Progressive Matrices Test*

The mean standardised score of the Raven Progressive Matrices Test was 105 in the ADHD group and 107 in the controls, but this difference was not statistically significant ($p = 0.70$; Table 1).

### *Mean Score of SWAN Rating Scale*

In the controls, the mean SWAN score was -0.24, which was similar to the mean score in the normal population.[20]

***Table 1. Demographic data and Raven Standard Progressive Matrices Test findings.***

| | ADHD group (n = 42) | Controls (n = 45) | p Value |
|---|---|---|---|
| Mean age (years) | 8 | 8 | 0.18* |
| Sex (male) | 91% | 78% | 0.98† |
| Form | | | 0.96† |
| Primary 1 | 14% | 13% | |
| Primary 2 | 51% | 49% | |
| Primary 3 | 35% | 38% | |
| Education level | | | 0.62† |
| Father | | | |
| Primary | 14% | 9% | |
| Secondary | 72% | 56% | |
| Tertiary or above | 14% | 36% | |
| Mother | | | 0.20† |
| Primary | 7% | 9% | |
| Secondary | 79% | 62% | |
| Tertiary or above | 14% | 29% | |
| Family monthly income (HK$) | | | 0.45† |
| 0-5,000 | 5% | 2% | |
| 5,001-10,000 | 26% | 20% | |
| 10,001-30,000 | 51% | 42% | |
| 30,001-50,000 | 12% | 18% | |
| 50,001-70,000 | 5% | 16% | |
| >70,000 | 2% | 2% | |
| Raven raw score, mean ± SD | 33.0 ± 9.2 | 35.6 ± 7.9 | 0.26 |
| Standardised score, mean ± SD | 105.1 ± 13.0 | 106.5 ± 13.6 | 0.70 |

Abbreviations: *ADHD = attention-deficit hyperactivity disorder; SD = standard deviation.*
* t *test.*
† *Chi-square test.*

### *Sources of Referral of Subjects with Attention-deficit Hyperactivity Disorder*

For ADHD subjects, the sources of referral to our psychiatric services were: child assessment centre in the catchment area of our psychiatric clinic (22, 53%); student health services (5, 12%); paediatricians in the same hospital (5, 12%); general practitioners / general outpatient clinics (5, 12%); private psychiatrists / other psychiatric services in public sector (3, 7%); and educational psychologists / clinical psychologists in the community centre (2, 5%).

### *Medication Status of Subjects with Attention-deficit Hyperactivity Disorder*

Twelve subjects (28%) were actively prescribed with methylphenidate. Three had a history of having taken methylphenidate, but not in the last 3 months. Among active users of methylphenidate, the mean daily dosage was 13.4 mg (ranging from 5 mg daily to 20 mg twice a day). All the subjects were devoid of methylphenidate intake for at least 48 hours before testing. One was taking the long-acting preparation of methylphenidate. There was no statistically significant difference in symptom counts for DISC-IV between subjects with (14.67, standard deviation [SD] = 2.02) and without (13.67, SD = 2.52) active usage of methylphenidate (*t* test, p = 0.11).

### *Diagnostic Interview Schedule for Children, Version IV Symptom Profile of Subjects with Attention-deficit Hyperactivity Disorder*

According to the symptom profile of DISC-IV, 9 subjects were of inattentive, 4 of hyperactive-impulsive, and 29 of combined subtypes. According to the diagnostic criteria by DSM-IV, 9 subjects had inattentive and 9 had hyperactive-impulsive symptoms. Among our ADHD subjects, the mean symptom count of the inattentive and hyperactive-impulsive subtypes were 7.6 and 6.7, respectively. The mean duration of the test date from the start of services in our psychiatric services was 7.0 months (range, 0-33 months).

### *Accuracy of Facial Emotion Recognition in Subjects with Attention-deficit Hyperactivity Disorder and Controls*

For the accuracy of facial emotion recognition, the mean scores were 8.8 (SD = 1.9, accuracy = 73%) and 8.9

***Table 2. Accurate versus inaccurate recognition of the 6 primary emotions.***

| Perceived emotion | Stimuli (%) | | | | | |
|---|---|---|---|---|---|---|
| | Happiness | Sadness | Surprise | Fear | Anger | Disgust |
| ADHD group | | | | | | |
| Happiness | **100.0** | 0.0 | 0.0 | 0.0 | 1.2 | 1.2 |
| Sadness | 0.0 | **83.7** | 4.8 | 8.5 | 0.0 | 3.5 |
| Surprise | 0.0 | 0.0 | **79.1** | 8.1 | 1.2 | 1.2 |
| Fear | 0.0 | 1.2 | 12.2 | **79.1** | 5.8 | 17.5 |
| Anger | 0.0 | 14.0 | 3.6 | 4.6 | **54.4** | 31.4 |
| Disgust | 0.0 | 1.2 | 0.0 | 0.0 | 36.0 | **45.3** |
| Control group | | | | | | |
| Happiness | **98.9** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sadness | 0.0 | **86.7** | 2.2 | 7.8 | 1.1 | 3.3 |
| Surprise | 0.0 | 0.0 | **77.8** | 7.8 | 0.0 | 1.1 |
| Fear | 0.0 | 1.1 | 17.6 | **82.3** | 3.3 | 8.8 |
| Anger | 1.1 | 11.1 | 3.3 | 1.1 | **60.0** | 44.5 |
| Disgust | 0.0 | 1.1 | 0.0 | 1.1 | 36.8 | **41.1** |

Abbreviation: *ADHD = attention-deficit hyperactivity disorder.*

***Table 3. Correlations between scores of the facial emotion recognition test and the raw and standardised scores of the Raven Standard Progressive Matrices Tests.***

| | ADHD group (n = 42) | Controls (n = 45) | Total (n = 87) |
|---|---|---|---|
| Raw scores | 0.36 (p = 0.05) | 0.39 (p = 0.01) | 0.35 (p = 0.001) |
| Standardised scores | 0.19 (p = 0.22) | 0.42 (p = 0.004) | 0.30 (p = 0.01) |

Abbreviation: *ADHD = attention-deficit hyperactivity disorder.*

***Table 4. Comparison of the facial emotion recognition ability among the 3 attention-deficit hyperactivity disorder (ADHD) subtypes and the controls.***

| | ADHD subtype | | | Controls (n = 45) |
|---|---|---|---|---|
| | Inattentive (n = 9) | Combined (n = 29) | Hyperactive-impulsive (n = 4) | |
| Mean score (% accuracy of facial emotion recognition test) | 8.1 (68%) | 8.8 (74%) | 10.3 (85%) | 8.9 (74%) |
| Standard deviation | 1.7 | 2.0 | 1.5 | 1.6 |

(SD = 1.6, accuracy = 74%) for the ADHD and control groups, respectively. This difference was not statistically significant (*t* test, p = 0.43).

### *Recognition of the Primary Emotions*

Across the 6 primary emotions, happiness showed the highest accuracy and disgust the lowest accuracy (Table 2). There was no statistically significant difference between ADHD and control subjects for each of the 6 primary emotions.

### *Correlation of Intelligence and Accuracy of Facial Emotion Recognition*

Positive correlations were found between the scores for the facial emotion recognition test and those of the Raven Progressive Matrices Test, which were statistically significant (Table 3).

### *Relationship between Inattention / Impulsivity and the Accuracy of Facial Emotion Recognition in Subjects with Attention-deficit Hyperactivity Disorder*

To evaluate such a relationship, analysis was performed as follows:

(1) Comparison of performance in the facial emotion recognition test among subjects in the 3 different ADHD subtypes (inattentive, hyperactive-impulsive, combined) and the control group is shown in Table 4. Subjects of the hyperactive-impulsive subtype

***Table 5. Comparison of attention-deficit hyperactivity disorder (ADHD) subjects with the worst performance in CPT-II (n = 10) and normal controls (n = 45).***

| | **ADHD with high omission error** | **ADHD with high commission error** | **ADHD with highest variability** | **ADHD with poorest detectability** | **Normal controls** |
|---|---|---|---|---|---|
| Mean score (% accuracy of facial emotion recognition test) | 8.6 (72%) | 9.2 (77%) | 9.4 (78%) | 9.2 (77%) | 8.9 (74%) |

showed the best performance among these 4 groups, but there was no statistically significant difference between the 4 groups when compared by one-way analysis of variance.

(2) The scores of the facial emotion recognition test of ADHD subjects were correlated with indices of inattention and impulsivity in CPT-II, namely the omission error, commission error, attentiveness (a measure of discrimination between hit of target and non-target), and variability (of hit reaction time). These variables were chosen because they were more related to the ADHD symptoms.[25,26] There was no significant correlation between facial emotion recognition and these parameters (omission error, $r$ = –0.067, p = 0.67; commission error, $r$ = 0.017, p = 0.91; variability, $r$ = 0, p = 1; detectability, $r$ = –0.093, p = 0.56).

(3) Ten ADHD subjects with the worst performance (most severe attention and impulsivity deficit) among the 4 selected indices in CPT-II were chosen. Their scores in the facial emotion recognition test were compared with those of the normal controls using the *t* test. This procedure was to ensure that the negative results encountered in the previous comparisons (between ADHD subjects and controls) were not affected by the former having milder inattention and impulsivity (Table 5). There was no statistically significant difference between these selected subgroups and the controls with respect to overall performance in the facial emotion recognition test.

## Discussion

We did not find the deficits in facial emotion recognition by ADHD children to be as reported previously in the literature.[9] Nor was there any significant correlation between the ability of facial expression recognition and the identified level of attention / impulsivity. We found a significant positive correlation between facial emotion recognition and the scores of the Raven Progressive Matrices Test (an index of intelligence). When we compared the scores of Raven Standard Progressive Matrices Test with the scores of facial emotion recognition in ADHD and control subjects, significant correlations in both groups were found. Thus, our study provides evidence that intelligence (especially non-verbal reasoning) is an important predictor of facial emotion recognition ability in children, even in those of normal intelligence. A recent review about the development of facial emotion recognition in children stated that consideration of likely confounding factors was important.[12] The latter include sex, age, socio-economic status of the family, and intelligence. In the present study, the control subjects were matched with those having ADHD with respect to these confounders. Therefore, our results reflect the effect of ADHD per se without the influence of potential confounders. Previous studies posing similar research questions and using a similar methodology to ours yielded positive results, but may have been influenced by confounding factors. In Singh et al's study,[9] the control sample was retrieved from a previous study in the general population, there being no specific matching for possible confounders. In the ADHD group, 68% were boys, and the sample had a relatively wide age distribution (5-13 years). Nor was the intelligence level of the subjects known. Without precise matching for such confounding factors, finding of any inferior performance in the ADHD group could have been biased.

There are 3 other studies that used the same set of photographs as stimuli to study facial emotion recognition in Asian populations,[10,27,28] which all yielded findings that were largely similar to ours. Happiness had the highest accuracy, followed by sadness, surprise, and fear. Anger and disgust were the least well recognised. Besides the order of the accuracy, the percentage of these 6 primary emotions identified accurately was also similar. In foreign studies of facial emotion recognition, a different pattern was noted. In Matsumoto and Ekman's study[23] about emotion recognition in adults, there was a much higher accuracy in recognising anger (85.3%) and disgust (79.3%). In the study of Singh et al,[9] disgust ranked third in terms of accurate recognition among the 6 primary emotions, yielding 76% in terms of accuracy in the tested children.

Significant differences between Asian and Caucasian population were observed, especially in recognising negative emotions. Emotion recognition development is affected by cue exposure. More exposure of cues can enhance such development. It was suggested that in Asian cultures (including Chinese and Japanese), expression of negative emotions is more subdued than in Caucasians, due to the influence of social norms. Evidently, Japanese recognised negative emotions more accurately only when they were shown in greater intensity.[28] It is possible that such cultural differences may have affected our findings. Thus, the results of previous studies on facial emotion recognition of ADHD children in Caucasian cultures were not replicated in our local Chinese population.

A study reported that the ADHD children with conduct problems performed better in emotion recognition than those with "pure" ADHD.[29] One possible explanation suggested was the influence of intelligence. But when we interpret such results in the light of our findings, another hypothesis may explain such a phenomenon. In a clinic-based ADHD sample, it is likely that the subjects have significant behavioural problems and co-morbidities from other psychiatric disorders.[30] The ADHD children recruited in our study were therefore likely to have been individuals with conduct problems rather than 'pure' ADHD subjects. For ADHD children with conduct problems, they are more likely to be exposed to more emotion cues (especial negative cues) than the so-called 'pure' ADHD children. This could have facilitated the development of facial emotion recognition, and even compensated for any possible intrinsic deficit. Therefore, the lack of significant difference in facial emotion recognition ability between ADHD and normal subjects in our study may be the result of psychosocial development interacting with neurodevelopmental aspects of facial emotion recognition. The former cancels out the effect of the latter, so the ability of facial emotion recognition of the children shows up as 'normal'.

It has been suggested that difference in social impairment exists among the 3 subtypes of ADHD children, namely inattentive, hyperactive-impulsive, and combined subtypes.[31,32] Subtype differences may have an important influence on the results. The so-called homogenous ADHD samples in different studies actually may not be homogenous. We made a comparison between ADHD subjects with these 3 subtypes and normal controls. Though the hyperactive-impulsive subtype (i.e. with a subclinical symptom profile in inattention domain) apparently performed better, the difference was not statistically significant. Moreover, interpretation of these findings is limited by the uneven distribution of the 3 ADHD subtypes in our sample, especially the small number in the hyperactive-impulsive subgroup.

We reviewed the correlation between inattention / impulsivity and the ability of facial emotion recognition. There was no direct correlation between inattention / impulsivity and facial emotion recognition ability. In an investigation of cross-modal integration of emotional expressions in college students, visual and auditory information about emotions appeared essential and unconstrained by attentional resources.[33] Our study only investigated static facial emotion recognition in the recruited children. In normal day-to-day social situations, they deal with dynamic facial changes together with other relevant environmental cues in order to behave appropriately. The constantly changing stimuli in daily life may require even greater attention than the static / distinct facial emotion used in our study. We may therefore have encountered a ceiling effect. The stimuli are not 'attention-demanding' enough to elicit differences between subjects with different attention and impulsivity levels, even if such differences really exist.

As for study limitations, the ADHD subjects were recruited from a psychiatric clinic and likely carried characteristics different from other subjects with ADHD in the community. Thus, our results may not be fully representative of all the ADHD subjects in the local population. Also, the effect of co-morbidities was not addressed. Evidence has accumulated on the high levels of co-morbidities (depressive and anxiety disorder; oppositional deviant disorder and conduct disorder; developmental delay) in children with ADHD.[30,34] These disorders may also have significant effects on the development of facial recognition ability. Third, the SWAN scale had no normative data in the local Chinese population at the time the study was performed. The cut-off score taken with reference to western populations may not be accurate enough to screen for potential ADHD subjects in the controls. Fourth, our study did not specifically review differences among the 3 ADHD subtypes and our analysis in this respect was limited by a small sample size. Further study of facial emotion recognition of ADHD children should also evaluate the effect of subtypes. Lastly, static stimuli of facial emotion expression were used in the current study. In actual practice, children actually deal with multiple dynamic cues, so our results may not be fully applicable to daily life. It is suggested that ADHD children have deficits in facial emotion recognition, yet this was not replicated in our local population.[9] The confounding factors such as socioeconomic characteristics may be the main contributors of the difference between ADHD and normal children in this respect. Cultural difference in facial emotion recognition may also contribute to the difference between our findings with those reported in other studies with similar methodology. In summary, development of facial emotion recognition ability in children is affected by various environmental and personal factors. Studies about facial emotion recognition ability conducted in Caucasians should not be generalised to our local population without considering such significant cultural differences.

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