Facial Emotion Recognition Skills and Measures in Children and Adolescents with Attention Deficit Hyperactivity Disorder (ADHD)

Aliki Economides, Yiannis Laouris, Massimiliano Conson, and Anna Esposito

Abstract Facial expressions have significant communicative functions; any changes in the facial muscles help disentangle meaning, control the conversational flow, pro-vide information as to the speaker/listener's emotional state and inform about inten-tion. Abnormalities in the recognition of facial expressions have been associated with psychiatric disorders. This review focuses on facial recognition abilities in chil-dren and adolescents with Attention Deficit Hyperactivity Disorder (ADHD). Using PRISMA guidelines original articles published prior to August 2019 were identi-fied focusing on the emotion recognition skills of children and adolescents with ADHD and the measures administered. 25 studies were identified with the major-ity (18) showing some deficits on emotion recognition in children/adolescents with ADHD compared to typically developing (TD) children. The results are synthesized in terms of the type of stimuli implicated (static vs. dynamic), the measures/tasks administered, whether authors differentiated among specific emotion dimensions in the analysis of results, the effect of comorbidity on emotion recognition, and whether greater deficits have been reported for some emotions compared to others. Studies on facial emotion recognition in children and adolescents with ADHD focused mainly on the recognition accuracy of facial emotions, showing inconsistent results and a

A. Economides · M. Conson · A. Esposito (B)
Dipartimento di Psicologia, Università Della Campania Luigi Vanvitelli, Caserta, Italy e-mail: iiass.annaesp@tin.it

A. Economides
e-mail: aliki.economides@unicampania.it

M. Conson
e-mail: conson.massimiliano@gmail.com

Y. Laouris
Cyprus Neuroscience & Technology Institute, Nicosia, Cyprus e-mail: laouris@cnti.org.cy

A. Esposito
International Institute for Advanced Scientific Studies (IIASS), Vietri Sul Mare, Italy

heterogenous use of measures. It is unknown whether the studies' participants followed therapeutic plans (other than pharmacotherapy) at the time of the study or before, a factor that may potentially have influenced the review's results.

1 Introduction

Facial expressions have been the focus of interest for more than 10 decades. As early as in the 1870 s, Charles Darwin wrote of facial expressions and emotions. It was not nevertheless until the 1970s that Ekman [30, 31] and Izard (1971, 1977) studied the field of perception and categorization of facial expressions. Though not having gone without criticisms, it is believed that the 'basic' emotions are six namely, fear, disgust, anger, happiness, surprise and sadness. Emotion recognition is crucial for social interaction and functioning and social cognition requires the ability to recognize, encode, and interpret emotions from faces [49]. Emotional understanding skills are hence essential for healthy social development in early childhood as one must decode and understand others' reactions, motivations and intentions [81] in everyday interactions. Emotional understanding skills are also closely related to developmental outcomes such as language, literacy, school readiness and mathematic skills in preschool [27, 71].

The recognition of emotional expressions improve with age [12] and develop gradually over time [24, 84], with some emotional expressions, i.e. happiness and sadness, being recognized earlier than others i.e. fear and disgust [38, 37]. It is now well established that happiness is the first to be recognized and with the greatest accuracy. Posamentier and Abdi [70] for example, found that infants produce their first smile 2 to 12 h after birth and Southam-gerow and Kendall [78] argued that by 4 years of age most children can pose basic facial expressions equally well to adults. Individual differences in emotion knowledge and understanding are key fac-tors in current and later prosocial behavior [58, 59] with children skilled in emotion recognition being reported as more likeable by their peers when compared to other same-aged children. In contrast, children with poor emotion recognition skills are at increased risk for being rejected or victimized by peers [59, 75]. Generally, it appears that young children with deficits in emotion recognition skills are at increased risk for several negative outcomes such as aggression, academic failure, poor emotional relationships and delinquency [18, 2].

Focusing on task demands children by 6 years of age, for example, were found to have a nearly perfect score when asked to point to which of the two faces was happy, angry, surprised, or sad but a good accuracy level was only achieved by the age of 10 when children were asked to select which of the two faces expressed the same emotion as a third face [13]. In a similar study by Mondloch, Geldart, Maurer, and Le Grand [60] children's performance reached the level of adults when asked to match an emotional photograph to either surprise, happiness, neutral, or disgust with accuracy increasing between 6 to 8 years of age. Whereas task demands influence emotion recognition accuracy, the age of 6 to 8 is a critical point of time as healthy children appear able to recognize the 6 basic emotions equally well to adults.

2 Facial Expressions and Psychopathology

Facial expressions have significant communicative functions; any changes in the facial muscles help disentangle meaning, control the conversational flow, provide information as to the speaker/listener's emotional state and inform about intention [34]. Understanding others' emotional facial expressions is a significant social-cognitive skill which helps to modulate one's behavior: for example, is a friend frightened or excited at the sight of a dog, is an observer becoming upset or surprised by an act of bravado?

Abnormalities in the recognition of facial expressions have been associated with psychiatric disorders in both children [8] and adults [39]. A failure to identify emo-tional facial expressions can have wide-reaching and long-term detrimental effects upon social behavior [43]. Although different child and adolescent clinical popula-tions have been shown to have deficits in facial expression recognition such as chil-dren diagnosed with Down syndrome [67], schizophrenia [17] conduct disorders [79], Attention Deficit Hyperactivity Disorder [49] and depressive disorder [21], autism is perhaps the most widely studied area in terms of developmental psychopathology and emotional deficits.

2.1 Attention Deficit Hyperactivity Disorder (ADHD)

ADHD is a neurodevelopmental disorder affecting people of all ages and of both genders. School-aged children with ADHD have been reported to suffer from social and emotional deficits, i.e. inability to effectively appraise the emotional state of oth-ers [16] and impairments in cognitive functions, i.e. inhibition, sustained attention, and executive planning [5]. Children with ADHD encounter many social problems, are generally less accepted by peers and lack social skills [29, 46]. Reduced social competence has been highly associated with the disorder [53] and the social problems encountered by these children constitute significant predictors of negative outcomes in later life i.e. adolescence and adulthood [61]. Factors related to emotional pro-cessing, and specifically deficient emotion recognition, has been discussed to play a key role [20].

The symptoms of ADHD begin in childhood (usually between the ages of 3 to 6), and for about half of the children, the symptoms continue into adolescence and adulthood. The primary symptoms of ADHD are (1) hyperactivity/impulsivity and (2) inattention and the specific presentation of symptoms may vary by age. Despite the lack of global consensus with regards to the prevalence of ADHD, it has been estimated that ADHD lies between 5.3% [68] and 7.1% [86] in children and adolescents and 1.2–7.3% in adults [35].

3 Objective

In this literature review we analyzed different studies highlighting the different aspects of facial emotion recognition in children with ADHD (with and without comorbidities) as well as the tasks administered to measure emotion recognition. The current review will complement past reviews [82] and meta-analyses [11] by solely focusing on studies that have implicated children and adolescent participants, by taking a closer look on the measures administered to assess emotion recognition and by considering the factor of comorbidity.

Despite Bora and Pantelis [11] having conducted an excellent review, the authors investigated social cognition in attention-deficit/hyperactivity disorder (ADHD) with comparisons having only been made among ADHD vs ASD and ADHD vs healthy controls. Uekermann et al. [82] included in their review studies from 1979–2009 with the authors having in detail argued the social cognition impairments in ADHD and Romani and colleagues 73 assessed face memory and face recognition in children and adolescents with attention deficit hyperactivity disorder. Nevertheless, in both papers detailed information such as the measures administered to assess affect recognition, the type of stimuli implicated, and the number of emotions investigated in each and across the studies included in the reviews have not been examined.

To our knowledge this is the first systematic review assessing emotion recognition in children and adolescents with ADHD that considered ADHD with comorbidities (e.g., ASD, CD and ODD) 'or other disorders' and the measures undertaken to assess emotion recognition.

4 Materials and Methods

4.1 Study Eligibility Criteria

We included academic articles (e.g. original articles and dissertations) focusing on facial emotion recognition in children and adolescents with ADHD (with and without comorbidities). This review considers studies published only between January 2000 and August 2019. Eligibility criteria hence constitute the study to have been published in a peer-reviewed journal from 2000 to 2019; participants to have been diagnosed with ADHD according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM) by the American Psychiatric Association (APA); to have been children and adolescents and their emotion recognition skills to have been investigated.

4.2 *Information Sources*

For this review we used Elsevier, PsycINFO, PsycArticles, Medline and PubMed databases. This review also benefited from other widely used search engines such as Google Scholar, recommendations from Web Libraries such as Mendeley, and reference lists from single articles, editorials and reviews.

4.3 *Search Strategy*

This review's search strategy followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to identify all relevant studies published after January 2000. The terms included in the search strategy were "Face recognition", "Facial emotion recognition", "Face recognition and ADHD", "ADHD comorbidities", "Facial expressions", "Emotion recognition measures in ADHD" and "Emotion recognition measures". Only studies in the English language were included. The full article was retrieved when its abstract met the eligibility criteria or when there was not enough information to exclude the article. The articles retrieved in full text were subsequently reviewed to determine whether our inclusion criteria were really met.

As regards the exclusion criteria, other literature reviews and meta-analyses as well as studies that implicated adults or focused on the pharmacotherapy effects in patients with ADHD were excluded. Furthermore, in the case that children or adolescents were not diagnosed according to the criteria of DSM, were excluded.

4.4 *Risk of Bias Across Studies*

Database bias: Articles only in the English language were evaluated.

5 Results

5.1 *Available Literature*

Using PRISMA guidelines, 112 articles were selected in the initial search. After excluding duplicates, the abstracts of the remaining 102 articles were scanned and 71 further articles were excluded based on the exclusion criteria in Sect. 4.3. Full texts of 39 articles were examined and 14 were further excluded as they did not meet the eligibility criteria, resulting in 25 studies being included in the review (Fig. 1). Table 1 presents the studies included in this systematic review and Table 2

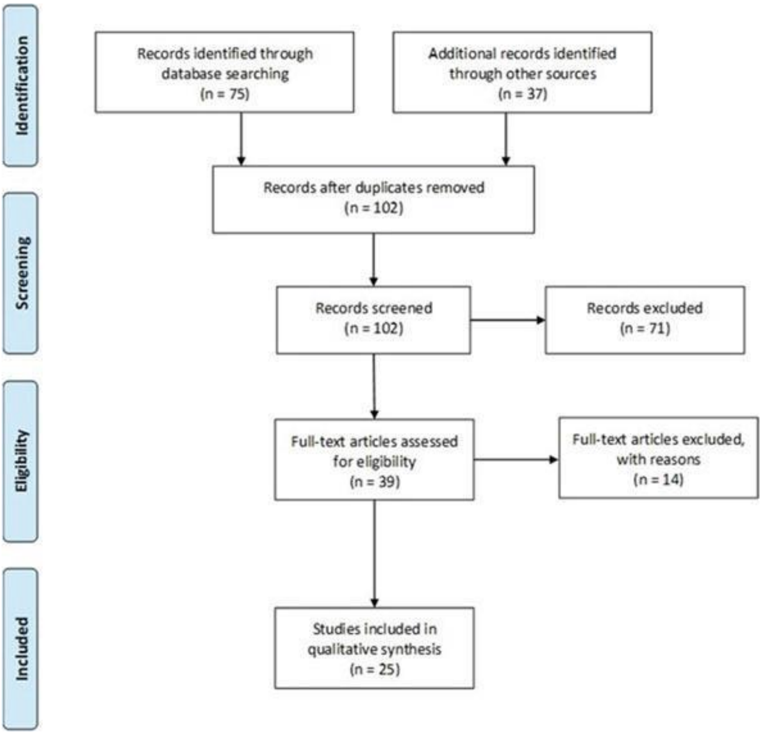

Fig. 1 Prisma flow chart

differentiates the studies included in the review based on the emotions investigated, whether authors differentiated among specific emotion dimensions in their analyses, and whether children with ADHD significantly differed from TD.

5.2 *Face Recognition in ADHD*

Table 1 presents 25 studies identified with the criteria set, with the majority (18) showing some deficits in emotion recognition in children with ADHD compared to typically developing children (TD) [1–5, 7–11, 13, 14, 16, 17, 21–23, 26]. There were 20 experimental, 1 genotype, 3 studies measuring brain and 1 study assessing both behavioral and neurophysiological parameters [24] in ADHD. All but one study [20] included a control group and ten included only boys [3–5, 7, 9, 16, 17, 19, 21, 22].

Table 1 Studies included in the systematic review

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
1. [16] 2000 Corbett & Glidden	ADHD (n = 37) (28 boys, 11 girls) 6.8–12.8 yrs *(10.08, 1.78)* TD (n = 37) (19 boys, 18 girls) 6.8–12.8 yrs *(9.49, 1.92)*	**Ekman and Friesen Pictures of Facial Affect** [32] 28 slides from the Pictures of Facial Affect set were presented for as long as necessary for the participant to give a response on a laminated sheet listing the six basic expressions and a neutral response	Anger Sadness Happiness Fear Disgust Surprise	TD children performed significantly better than ADHD children. However, all groups comparisons were based on total scores collapsed across the six basic emotions hence the results do not offer any insights into the specific type of facial affect that ADHD children will express difficulties in processing
2. [14] 2000 Cadesky, Mota & Schachar	ADHD (n = 86) (69 boys, 17 girls) 7–13 yrs *(9.0, 1.4)* CD (n = 24) (20 boys, 4 girls) *(9.3, 1.6)* ADHD and CD (n = 6) (54 boys, 7 girls) *(9.3, 1.5)* TD (n = 27) (18 boys, 9 girls) *(9.3, 1.5)*	**Diagnostic Analysis of Non-Verbal Accuracy [63]** Children had to interpret emotional cues from pictures of facial expressions and recordings of voices drawn from the Diagnostic Analysis of Non-Verbal Accuracy (DANVA). The DANVA contains 4 subtests that were used by this study: Adult Facial Expressions [64], Child Facial Expressions, Adult Paralanguage [6], and Child Paralanguage [63]. For all subsets but the Child Paralanguage, each emotion was presented 6 times. For the Child Paralanguage subset 3 happy, 6 sad, 3 angry and 4 fearful stimuli were presented	Anger Sadness Fear Happiness	Children with conduct problems (CP) and ADHD were significantly less accurate at interpreting all emotions except anger than TD children. However, children with ADHD + CP differed in the type of errors made: the ADHD group's errors were generally random in nature, whereas the CP group tended to misinterpret emotions as anger. The ADHD + CP group performed better than the ADHD and CP groups, was as accurate as the control group and displayed a unique pattern of errors. The authors attributed the errors made by the ADHD group to deficits in encoding stimuli due to inattention rather than to specific distortions in interpreting emotions

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
3. [28] Downs & Smith	ADHD/ODD boys (n = 10) 5.8–9.9 yrs *(8.3, 1.0)* High functioning autistic boys (n = 10) 5.8–9.9 yrs *(7.10, 1.1)* TD boys (n = 10) 6.4–9.2 yrs *(7.7, 1.2)*	**Questions on Emotional Understanding [45]** Participants were presented with questions to determine their level of emotional understanding. Each child was assessed beginning at level 1 and continuing through to level 5. Level 1–identified emotional facial expressions in photographs; Level 2–identified emotional facial expressions in schematic drawings, Level 3–identified situation-based emotions; Level 4–identified desire-based emotions; Level 5–identified belief-based emotions	Not defined	The ADHD/ODD group answered significantly fewer total questions correctly on the theory of mind emotional understanding task than did the nonclinical group. The ADHD/ODD group also displayed a trend toward having a significantly lower level of emotional understanding than both the nonclinical group and the autism group
4. [3] 2004 Aspan et al.	Boys with the combined subtype of ADHD (n = 22) 13–16 yrs *(14.2, 0.2)* TD boys (n = 22) 13–16 yrs *(14.2, 0.2)*	**Facial Expressions of Emotion-Stimuli and Tests (FEEST) [88]** The computerized and extended version of the original 60 faces test from the Pictures of Facial Affect [32], Facial Expressions of Emotion-Stimuli and Tests (FEEST), was used. Participants were asked to choose a label for the emotional content of the faces visible on the screen. The images were displayed in a random order	Anger Sadness Happiness Fear Disgust Surprise	Adolescents with ADHD were more sensitive in the recognition of disgust, were significantly worse in the recognition of fear, and showed a tendency toward impaired recognition of sadness ((1,40) = 3.771, < 0.056). The recognition of anger, happiness and surprise did not show significant differences between the two groups. Hyperactivity measures were positively correlated with the recognition of disgust and inversely correlated with the recognition of fear

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
5. [66] Pelc, Kornreich, Foisy & Dan	Predominantly hyperactive-impulsive type of the ADHD disorder (n = 30) (23 boys, 7 girls) 7–12 yrs *(8.0, 1.2)* Age- and sex-matched TD children (n = 30) (23 boys, 7 girls)	**Set of Emotional Facial Stimuli [44]** Emotional facial expressions performed by 2 male and 2 female actors were presented to all participants and to one participant at a time. A series of intermediate expressions differing in emotional intensity levels by 10% steps was constructed based on the neutral face of the same actor and using the computer program Morph 1.0. The 30 and 70% intensity levels were used for the present study. In total 16 stimuli were presented in a random order: a set of 2 (intensity levels: 30 and 70%) × 4 (emotions: happiness, anger, disgust, and sadness) × 2 (actors). Each of the 16 expressions were rated by participants on four 7-point intensity scales	Happiness Anger Sadness Disgust	Children with ADHD made significantly more emotional facial expressions decoding errors than control children. No significant differences were found in emotional facial expressions decoding accuracy between children with ADHD and control children for happiness and disgust. Decoding accuracy was significantly lower in children with ADHD than in TD children for anger with 70% intensity. Decoding accuracy was also lower in children with ADHD than in control children for sadness at all intensities. Children with ADHD were furthermore unaware of the decoding errors when compared to the control group, manifesting significantly lower awareness of errors for anger

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
6. [89] Yuill & Lyon	Task 1 Boys with ADHD (n = 19) 5 with comorbid ODD 5.10–11.9 yrs *(8.11)* TD boys (n = 19) 7.2mo–11 yrs (*8.11)* Task 2 Boys with ADHD (n = 17) 5.8–10.6 yrs *(8.2)* TD boys (n = 13) 5.0–6.0 yrs (*5.5*)	**Non-emotional and emotion matching tasks** Task 1 Participants were presented with a set of six photographs to match to six situations (e.g. Happy: Thomas has just found his lost puppy). For the non-emotional task, a further set of six photographs were presented where the facial expressions were posed as neutral (e.g. Hot (Sunglasses): Thomas has just been out in the sunshine). The photographs were posed by an 11-year-old boy and were validated by 5 adults Task 2 Participants performed the same tasks, but with an 'inhibitory scaffolding' procedure to prevent impulsive responding	Happiness Fear Sadness Anger Surprise Disgust	Task 1 Boys with ADHD performed more poorly than the control group in matching faces to situations. Performance on the emotion matching task was also lower than on the non-emotion task. Boys with ADHD also performed poorly when making judgements about non-emotional characteristics of faces. There were no significant performance differences in the ADHD group between those diagnosed with ODD and those not Task 2 The ADHD group performed equally well to the control group on the non-emotion task, but poorer than the control group on the emotion task. There was a significant difference between the emotion and non-emotion task for the ADHD group with the control group performing equally well on both tasks. The effect of scaffolding was group- and task-specific: it helped the boys with ADHD more in the non-emotion task than in the emotion task. Children with ADHD who failed any situation-matching task were still able to label the emotional expressions correctly in 85% of cases

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
7. [42] Guyer et al.	Bipolar disorder (BD) (n = 42) 7–18 yrs *(12.8, 2.5)* Severe mood dysregulation (n = 39) *(11.8, 2.1)* Anxiety and/or major depressive Disorders (n = 44) *(13.1, 2.5)* ADHD or CD (n = 35) *(14.8, 1.6)* 25 boys, 10 girls TD (n = 92) *(14.4, 2.4)* 47 boys, 45 girls	**Diagnostic Analysis of Nonverbal Accuracy (DANVA) [63]** Participants were presented with a face-emotion labeling task. Each computer-administered subtest included 24 photographs of child or adult models (12 female, 12 male) displaying equal numbers of high and low-intensity expressions of happiness, sadness, anger, and fear. Faces appeared for 2 s. In a forced-choice format, participants indicate by button-press which emotion a face expressed	Happiness Sadness Anger Fear	ADHD/CD patients performed similarly to controls on the face-emotion labelling tasks. Face labeling ability did not differ based on the age of the face or the specific emotion displayed
8. [87] Williams et al.	Unmedicated ADHD boys (n = 51) 8.0–17.0 yrs *(13.79, 2.33)* TD boys (n = 51) 8–17 yrs *(13.09, 2.39)*	**Gur faces [41]** Evoked expressions of facial emotion (eight different individuals; four males, four females) acquired from a standardized series were presented in black and white during an ERP recording. Participants selected the verbal label corresponding to each facial expression (fear, anger, sadness, disgust, happiness, or neutral) and percentage accuracy was recorded	Fear Happiness Anger Sadness Disgust	Unmedicated ADHD participants were significantly more anxious and depressed than healthy controls. Children with ADHD were significantly worse in recognizing anger and fear. These expressions tended to be misidentified as neutral or sadnes

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
9. [77] Sinzig, Morsch & Lehmkuhl	Autism + ADHD (n = 21) (20 boys, 1 girl) 6.1–18.2 yrs *(11.6, 18.2)* Autism (n = 19) (17 boys, 2 girls) 8.1–18.9 yrs *(13.6, 3.4)* ADHD (n = 30) (28 boys, 2 girls) 7.1–17.9 yrs *(12.7, 3.1)* TD (n = 29) (22 boys, 2 girls) 7.6–17.6 yrs *(12.8, 2.9)*	**Frankfurt Test and Training of Social Affect (FEFA) [10]** Facial affect recognition was assessed with a computer-based program used for teaching emotion processing, the Frankfurt Test and Training of Social Affect (FEFA) using faces and eye-pairs as target material. The FEFA comprises 50 photographs of faces and 40 photographs of eye-pairs according to the “pictures facial affect” and the six basic emotions according to Ekman and Friesen. Furthermore, three attention-tasks (Sustained attention, Inhibition, Set-Shifting) were administere	Happiness Fear Sadness Anger Disgust Surprise	Facial affect recognition was impaired in children suffering from ADHD symptoms only and, Autism + ADHD. Children with ADHD were impaired on both facial affect recognition and recognition of emotion from eye-pairs when compared to TD children. Children with Autism + ADHD were worse in the recognition of happiness (eye-pairs) and surprise (faces) when compared to both TD children and Autistic children. Children with ADHD scored lower on the recognition of happiness (eye-pairs) when compared to TD children
10. [9] Boakes, Chapman, Houghton & West	ADHD boys (n = 48) 7.10–12.3 yrs *(10.2, 1.4)* TD boys (n = 48) *(10.3, 1.3)*	**Facial Affect Interpretation Task (FAIT)** The stimulus expressions used in the Facial Affect Interpretation Task (FAIT) were created from scenes drawn from two contemporary television shows. 24 static, 24 dynamic-decontextualized and 24 dynamic-contextualized stimuli were presented in either a cartoon or a real-life portrayal mode	Happiness Fear Sadness Anger Disgust Surprise	Boys with ADHD were significantly impaired in the interpretation of disgust and fear when compared to controls. Results also suggested a trend towards impairments for boys with ADHD in the interpretation of surprise. Although a main effect indicated significant overall performance increments across these three levels, participants in the ADHD and TD did not appear to benefit differentially from increasing levels of supplemental information

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
11. [19] Da Fonseca, Sequier, Santos, Poinso & Deruelle	Combined subtype of ADHD (n = 27) (21 boys & 6 girls) 5.0–15.0 yrs (*10.2, 2.7*) TD (n = 27) (21 boys & 6 girls) 5.0–15.0 yrs (*10.3, 2.7)*	Experiment 1 40 digitized colored photographs (10 of each emotion investigated) were acquired from popular French media magazines. The character's face and part or full body figured on the photographs. Target faces consisted of 26 pictures of adult faces and 16 pictures of children faces with an equal number of male and female characters. The pictures were validated in a pilot study with 16 TD children. After the presentation of each stimulus children were presented with three response-options (the target face and two distracter emotions) Experiment 2 Stimuli comprised 60 colored photographs taken from popular French media magazines. These photographs were scanned and used as visual scenes in which either a face expressing an emotion, or an object was masked. Visual scenes masking an object or face were carefully matched in terms of complexity and the number of characters and objects contained in the scene. Target faces and target objects were masked by a white Circle. The stimuli were validated in a pilot study with 16 TD children.	Anger Sadness Fear Happiness	Experiment 1 TD children performed generally significantly better than children with ADHD. For all participants both Happiness and Anger were better recognized than Fear and Sadness. No significant Group by Emotion interaction was found Experiment 2 Children with ADHD were less accurate than TD using contextual information to understand emotions. TD children performed significantly better than children with ADHD. Both groups performed significantly worse on the Emotion recognition than on the Object recognition condition

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
12. **[40]** Greenbaum et al.	Fetal Alcohol Spectrum Disorders (FASDs) (n = 33) (16 boys and 17 girls) 6.0–13.0 yrs *(9.20)* ADHD/33% had 1 or more comorbid conditions (n = 30) (24 boys and 6 girls) *(9.30)* TD (n = 34) (18 boys and 16 girls) *(8.90)*	**Minnesota Test of Affective Processing (MNTAP) [51]** Emotion processing was assessed using 4 of the 6 subsets from the Minnesota Test of Affective Processing (MNTAP). Affect Match, Affect Naming, Affect Choice, and Prosody Content. Affect Match required the child to determine whether the same or different emotions were conveyed on the faces of 30 pictures presented. In Affect Naming, the child was asked to select the cartoon face with the same facial expression as in the photographed face. In Affect Choice the child had to touch the face on the computer screen depicting the emotion generated verbally by the computer. In Prosody Content children had to state whether voice and content matched	Not defined	FASD group performed significantly worse than ADHD and control groups on Affect choice. No comparisons are provided for ADHD and controls.
13. [65] Passarotti, Sweeney, & Pavuluri	Combined subtype of ADHD (n = 14) (9 boys, 5 girls) 10–18 yrs *(13.00, 2.35)* TD (n = 19) (9 boys, 10 girls) *(13.53, 3.16)*	**Gur faces [41]** Participants underwent an fMRI scanning session when they were administered a block design 2-back working memory task with emotional faces for approximately 7 min. The paradigm involved two runs with one condition each. The first run consisted of blocks of angry and neutral faces and the second run consisted of blocks of happy and neutral faces. On each trial a face stimulus with a certain emotion or a neutral expression was presented for 3 s and participants responded by pressing a response key if they saw the same face as the one presented two trials earlier	Anger Happiness	For reaction time, there was only a significant effect of face emotion; the reaction time for angry faces was significantly slower than for neutral faces across groups. There was a non-significant trend for the ADHD group to be less accurate than TD childre

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
14. [4] Bal	ADHD (n = 33) (23 boys, 10 girls) (*9.33*, *1.76*) 12 were on medication 14 had comorbidities TD (n = 38) (18 boys, 16 girls) (*9.94*, *1.63*)	**Dynamic Affect Recognition Evaluation (DARE) [69]** Morphed images in a video like format starting with a neutral expression and slowly transitioning into one of the 6 basic emotions. The DARE software was synchronized with the eye tracking and physiological monitoring equipment. The participants were asked to identify which of the six emotion labels best represented the emotion that had just been presented	Anger Disgust Fear Happiness Sadness Surprise	ADHD group made significantly more errors than the control group to anger and disgust. In the ADHD group 36% of responses to anger were disgust, and 22% of responses to disgust were anger and 17% were fear. Analysis indicated significant differences between boys and girls on disgust errors only with boys making significantly more errors than girls. No differences among medicated and unmedicated ADHD children were found. The ADHD group was not significantly slower or faster in identifying the emotions than the control group
15. [76] Schwenck et al.	ADHD (n = 56) (38 boys, 18 girls) (28 unmedicated, 28 medicated) 8.2–17.0 yrs *(12.34, 2.54)* TD (n = 28) (19 boys, 9 girls) *(12.49, 2.55)*	**Karolinska Directed Emotional Faces [55]** Emotion recognition was assessed using the Morphing Task (MT). The MT was a self-developed task in which children were shown 60 film clips each of 9-s length with a neutral facial expression changing continuously to an emotional expression. Participants were asked to press a key as soon as they had recognized which emotion was presented and to name the correct emotion	Happiness Fear Sadness Disgust Anger	No differences were found between children with ADHD without medication and the control group in neither the reaction time, variability of reaction time nor the number of correctly identified emotions. This result applied for all basic emotions assessed. Furthermore, medication did not influence emotion recognition performance
16. [50] Kochel et al.	ADHD boys (n = 16) TD boys (n = 16) 8.5–11.8 yrs (*10.16*, *1.10*)	**EEG Emotional Go/NoGo task with faces from the Karolinska Directed Emotional Faces (KDEF) [55]** A total of 24 different faces from the emotion categories anger, sadness, happiness, and neutral were displayed by 3 women and 3 men. An emotional task required inhibition, or a button press for a certain emotional face (e.g., “do not press the button when a happy/sad/angry face is presented”). A non-emotional task was used as a control condition	Anger Sadness Happiness	Children with ADHD made more errors compared to the control group. Boys with ADHD tended to make more recognition errors for anger compared to the control group. These group differences were not seen in the recognition of sadness, happiness, and neutral faces. Longer RT were required for the emotional compared to the neutral task. For both groups the longest RT were required anger and shortest for happiness. ADHD did not differ from TD in RT

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
17. [54] Ludlow et al.	ADHD boys (n = 24) 12–15 yrs *(13.59, 0.82)* TD age and verbal IQ matched with mild to moderate learning disabilities (n = 24) (15 boys, 9 girls) 12–16 yrs *(14.13, 1.22)*	**Emotion Evaluation Test (EET) from The Awareness of Social Inference Test (TASIT) [57]** The EET comprises a series of 28 short (15–60 s) videotaped vignettes of trained professionals interacting in everyday situations and portraying one of seven emotions, presenting 4 vignettes for each emotion. 12 segments suggest a positive emotional state and 16 segments suggest a negative emotional state. Participants' recognition of spontaneous emotional expressions was assessed	Happiness Disgust Fear Anger Sadness Surprise	No significant differences were found between the participants diagnosed with hyperactive and combined types of ADHD. ADHD participants overall recognized less emotions accurately than control participants. There was overall better recognition of positive than negative emotions. Happiness was recognized better than all the other emotions, whereas fear and disgust were recognized worse than the other emotions. TD performed significantly better in the recognition of anger, surprise, sadness and fear. Verbal ability and age were not significant predictor of EET scores. The use of medication in the ADHD group did not have significant effects on the EET scores
18. [62] Noordermeer et al.	ADHD (n = 82) (55 boys, 27 girls) *(16.0, 3.1)* ADHD + ODD (n = 82) (55 boys, 27 girls) *(16.0, 3.0)* TD (n = 82) (55 boys, 27 girls) *(16.0, 3.3)*	**Identification of Facial Emotions [23]** Participants were shown a picture of an adult face displaying an emotion and had to compare the expressed emotion with the target emotion (happy, sad, and angry), by pressing a yes/no button. Pictures remained on screen until a response was given. For every emotion, a 50/50 distribution of pictures that contained the target emotion and pictures that contained a non-target emotion was shown. The sequence of the tested target emotions was randomly assigned	Happiness Sadness Anger	Groups did not differ in the percentage of correct responses during happy, angry, or afraid trials. Mean RT for angry trials did differ between groups; the ADHD + ODD group showed slower mean RTs for correct responses compared with controls indicating difficulties in correctly identifying angry facial emotions. The ADHD-only group did not differ from TD.

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
19. [83] van Goozen et al.	ADHD boys (n = 194) 10.0–17.0 yrs (*13.95, 1.82*)	Genotype study to assess the links between COMT genotype and aggression. Participants completed tasks assessing executive function (response inhibition and set shifting), empathy for fear, sadness and happiness, and fear conditioning. To assess participants' cognitive and affective empathy three clips depicting the emotions of sadness, happiness and fear were edited from cinematic films. After each clip participants completed a questionnaire concerning the recognition of the emotions of the main character (cognitive empathy) and their own emotions while viewing the clip (affective empathy). Participants were also asked to explain the reason for the emotion (-s) identified in the main character and themselves	Sadness Fear Happiness	COMT Val allele carriers showed poorer response inhibition and set shifting abilities, reduced fear empathy and reduced autonomic responsiveness (lower SCRs) to the conditioned aversive stimulus. COMT Val158Met did not predict impairments in recognizing others' emotions or affective empathy for happiness or sadness
20. [7] Berggren al.	ASD (n = 35) (18 boys, 17 girls) 8.6–15.4 yrs (*11.6, 1.8*) ADHD (n = 32) (17 boys, 15 girls) 8.6–15.9 yrs (*11.1, 2.1*) TD (n = 32) (18 boys, 14 girls) 9.4–15.5 yrs *(11.7, 1.8)* Age matched groups	**The Swedish version of the computer-based Frankfurt Test for Facial Affect Recognition (FEFA) [10]** The FEFA test uses the cross-cultural concept of the 6 basic emotions and the neutral affective state to assess explicit FAR skills by verbal labelling of the emotions expressed in the eye regions and in whole faces. There are between 3 to 9 items for each basic emotion on the eyes test, and 5 to 9 for the face test. The total score for the faces and eyes test, the number of correct answers per basic emotion and response times in second for both tests were assessed	Happiness Sadness Anger Surprise Disgust Fear	The ADHD group responded faster than the ASD group for global FAR. No differences between ADHD and TD were found. No differences on accuracy for specific emotions were found between TD and ADHD

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
21. [80] Tehrani-Doost et al.	ADHD boys (n = 28) 7.0–12 yrs *(8.75, 1.39)* TD boys (n = 27) *(9.46, 1.45)*	**Cohn Kanade AU-coded Facial Expressions Database [48]** A computerized facial emotion recognition task based on the Cohn- Kanade face database was used. One hundred faces were randomly divided in happy, sad, angry and neutral expressions. Each emotion was shown to the participants 25 times, using three male and two female faces randomly	Happiness Anger Sadness	Children with ADHD were significantly worse in recognizing all emotions compared to TD. The two groups showed no difference in recognizing the neutral faces. The time spent in recognizing happy faces was higher in the ADHD. Both groups were better to detected happy and neutral faces than the angry ones. The ADHD group recognized happy and neutral targets more accurately than sad targets and there was a significant interaction between angry and sad targets recognition and inattention
22. [74] Sarraf Razavi et al.	Combined subtype ADHD boys (n = 19) 7.0–11.0 yrs *(9.21, 1.13)* TD boys (n = 19) 7.0–11.0 yrs (*9.73*, *1.04*)	**Cohn Kanade AU-coded Facial Expressions Database [48]** This study aimed to compare the gamma band oscillations among patients with ADHD and TD during facial emotion recognition. Stimuli were 6 Caucasian faces (3 females and 3 males) expressing happy, angry, sad and neutral emotions. Each emotion was repeated 60 times in a random way. Participants had to respond by pressing one of the four buttons (representing the emotions under investigation) on a joystick	Happiness Anger Sadness	Individuals with ADHD differed from TD children during early facial expression recognition. ADHD children showed a significant reduction in the gamma band activity when compared to healthy controls in occipital site and a significant decrease for happiness and anger in the left and right occipital, respectively

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
23. [47] Jusyte, Gulewitsch & Schönenberg	ADHD (n = 26); 13 ADHD Combine; 10 ADHD Inattentive (17 boys, 9 girls) (24 unmedicated, 2 medicated with methylphenidate) 10.0–14.0 yrs *(11.68, 1.65)* TD (n = 26) (13 boys, 13 girls) 10.0–14.0 yrs *(11.73, 1.30)*	**Radboud Faces Database [52]** Color photographs of 4 child models served as stimuli. The stimulus material was created by blending the neutral and emotional expressions of every model identity, resulting in six distinct neutral-emotional sequences for each model. For every sequence, a set of 51 images with intensity levels ranging from completely neutral to full blown expression were extracted (2% increment steps) and presented to all participants. The participants were instructed to press a button as soon as they were able to correctly recognize the depicted expression. The sequence was then immediately stopped, the face disappeared, and the perceptual intensity as well as selected emotion category were recorded	Happiness Anger Fear Disgust Surprise Sadness	There was an overall lower accuracy across all emotions in the ADHD as compared to the control group; happy expressions were associated with the highest and fearful with the lowest accuracy rates. Surprise was better recognized than disgust. Some emotions, such as happiness, were recognized at lower intensity levels than others whereas disgust and surprise did not differ from each other. The results were not attributed to impulsive or inattentive responding in the ADHD as compared to the control group. In accordance with previous reports, disgust was frequently confused with anger, fear with surprise, and sadness with fear or anger, a characteristic pattern that was evident in both groups (Kats-Gold et al., 2007; Schönenberg et al., 2014)
24. [72] Rinke et al.	ADHD (n = 29); Unmedicated 24 h before the study 2 with comorbid developmental disorder (24 boys, 5 girls) 7.0–17.0 yrs *(12.09, 2.76)* TD (n = 21) (9 boys, 12 girls) 8.0–17.0 yrs *(12.08, 3.00)*	**Pictures of Facial Affect** [32] Behavioral and neurophysiological study. Children had to undergo among others, the emotional continuous performance task (ECPT) and the facial emotion matching (FEM) task. In the ECPT, different emotional stimuli were presented sequentially, and the participant had to get prepared for an action (go-trial), inhibit an action (no-go-trial), or simply ignore the stimulus. In the FEM task different human facial emotion expressions were presented and the child was asked to choose one of the model pictures showing an equal emotion as the one presented in the center of the screen	Happiness Anger Fear Disgust Surprise Sadness	Children with and without ADHD did not differ on the behavioral performance tasks as well as the neurophysiological measurements. Older children showed better recognition accuracy of the emotion anger than the younger children and were faster in their responses

(continued)

Table 1 (continued)

No. of study date & authors	No. and type of participants; age (mean, sd)	Emotion recognition task & stimuli	Emotions investigated	Results
25. [1] Airdrie et al.	ADHD with or without comorbid CD (n = 63) (47 boys, 16 girls) 11.0–18.0 yrs (*14.20, 2.09*) TD (n = 41) (21 boys, 20 girls) 11.0–18.0 yrs (*15.50, 2.70)*	**Pictures of Facial Affect** [32] Emotion recognition task with congruent eye tracking. 60 faces from the Ekman and Friesen series of facial affect (happiness, fear, anger, sadness) and neutral were presented. Each emotion was morphed with its corresponding neutral expression to create a 50 and 75% intensity expression. An equal number of male and female target faces appeared, and slides contained an equal number of each emotion presented at each intensity	Happiness Fear Anger Sadness	Emotions high in intensity were better recognized than emotions low in intensity. Highest accuracy scores were found for happy faces, followed by neutral, fear, angry and sad. Groups differed only in the recognition of fear and neutral emotions. Children with ADHD + CD were less accurate than children with ADHD and HC in the recognition of fear and neutral expressions. Children with ADHD did not differ from HC in the recognition of fear and neutral expressions. There was greater tendency to misinterpret fear faces as angry faces for children with ADHD + CD than ADHD and HC, with no differences being found between children with ADHD and H

Table 2 Emotions examined, differentiation among specific emotion dimensions across studies, and impairments in children with ADHD compared to TD across the emotions and studies included in the review

Emotions under study	Sadness	Fear	Happiness	Disgust	Surprise	Anger	Summary
Study ID							
1							ADHD children were significantly impaired compared to TD on all the emotions investigated. The authors did not differentiate the specific emotion dimensions in their analyses
2	*	*	*			×	Children with ADHD were significantly impaired compared to TD on the emotions of sadness, fear and happiness but not anger. The authors differentiated among specific emotion dimensions in their analysis
3							The authors did not define the emotions investigated in their study.
4	×	*	×	×	×	×	Children with ADHD were significantly impaired compared to TD only on the emotion of sadness. The authors differentiated among specific emotion dimensions in their analysis
5	*		×	×		*	Children with ADHD were significantly impaired compared to TD only on the emotions of sadness and anger. Emotion recognition accuracy did not differ on the emotions of happiness and disgust. The authors differentiated among specific emotion dimensions in their analysis

(continued)

Table 2 (continued)

6							ADHD children were significantly impaired compared to TD. The authors did not differentiate the specific emotion dimensions in their analyses
7							ADHD children did not significantly differ from TD. The authors did not differentiate the specific emotion dimensions in their analyses
8	×	✱	×	×		✱	Children with ADHD were significantly impaired compared to TD on the emotions of fear and anger. Emotion recognition accuracy did not differ on the emotions of happiness, sadness and disgust
9	×	×	✱	×	✱	×	Children with ADHD were significantly impaired compared to TD on the emotions of happiness and surprise. Emotion recognition accuracy did not differ on the emotions of sadness, fear and disgust
10	×	✱	×	✱	×	×	Children with ADHD were significantly impaired compared to TD on the emotions of fear and disgust. Emotion recognition accuracy did not differ on the emotions of sadness, happiness, surprise and disgust
11	≡	≡	≡			≡	Children with ADHD were significantly impaired compared to TD on the emotions of sadness, fear, happiness and anger. Despite the presence of a main effect for group and emotion no significant group by emotion interaction was found

(continued)

Table 2 (continued)

12							The authors did not define the emotions investigated
13			×			×	ADHD children did not significantly differ from TD children on the emotions of happiness and anger that the authors investigated. The authors differentiated among specific emotion dimensions in their analysis analyses
14	×	×	×	✱	×	✱	Children with ADHD were significantly impaired compared to TD on the emotions of disgust and anger. Emotion recognition accuracy did not differ on the emotions of sadness, fear, happiness and surprise between the two groups
15	×	×	×	×		×	The authors did not find any significant differences on the recognition accuracy of the emotions investigated, i.e. sadness, fear, happiness, disgust and anger, between children with ADHD and TD children
16	×		×			✱	Children with ADHD were significantly impaired compared to TD only on the emotion of anger. Emotion recognition accuracy did not differ on the emotions of sadness and happiness

(continued)

Table 2 (continued)

17	✱	✱	×	×	✱	✱	Children with ADHD were significantly impaired compared to TD on the emotions of sadness, fear, surprise and anger. Emotion recognition accuracy did not differ on the emotions of happiness and disgust. The authors investigated all six basic emotions and differentiated among specific emotion dimensions in their analysis
18	×		×			×	Children with ADHD and TD children did not differ on any of the emotions investigated i.e. sadness, happiness and anger
19	×	×	×				Children with ADHD and TD children did not differ on any of the emotions investigated i.e. sadness, fear and happiness
20	×	×	×	×	×	×	Children with ADHD and TD children did not differ on any of the six basic emotions investigated
21	✱		✱			✱	Children with ADHD were significantly impaired compared to TD on the recognition accuracy of sadness, happiness and anger
22	~		~			~	The authors examined differences in gamma band oscillations between children with ADHD and TD.

(continued)

Table 2 (continued)

23	≡	≡	≡	≡	≡	≡	Children with ADHD were significantly impaired compared to TD on all six emotions investigated. Despite the presence of a main effect for group and emotion no significant group by emotion interaction was found
24							Children with ADHD did not significantly differ from TD children on the emotions investigated. The authors did not differentiate the specific emotion dimensions in their analyses
25	×	✱	×			×	Children with ADHD were significantly impaired compared to TD only on the emotion of fear. Emotion recognition accuracy did not differ on the emotions of sadness, happiness and anger

In [3, 12] the authors did not define the emotions investigated.
ADHD children did not significantly differ from TD/The authors did *not differentiate* the specific emotion dimensions in their analyses.
ADHD children were significantly impaired compared to TD/The authors did *not differentiate* the specific emotion dimensions in their analyses.
✱Children with ADHD were significantly impaired compared to TD/The authors *differentiated* among specific emotion dimensions in their analysis.
× ADHD children did not significantly differ from TD/The authors *differentiated* among specific emotion dimensions in their analysis analyses.
≡ ADHD children were significantly impaired compared to TD/The authors *differentiated* among specific emotion dimensions in their analysis analyses/There was no significant group by emotion interaction.
~ The authors examined differences in gamma band oscillations between children with ADHD and TD children.

5.3 The Effect of Gender and Age

Generally, among the studies that implicated both genders, more boys with ADHD participated than girls. Whereas in Corbett and Glidden [1] gender did not significantly differ between groups, when gender and age were added as covariates boys differed from girls on the perception of affect measures. In the preliminary analyses of Greenbaum et al. [12] albeit the presence of a significant gender effect due to the high male to female ratio in the study, the authors did not proceed with including it in subsequent analyses as this proportion reflected the typical gender rates of ADHD seen in the general hence not deemed as problematic. In contrast, when age and gender were added as covariates in Airdrie et al. [26] emotion recognition accuracy did not differ in gender and only approached significance in age. In Guyer et al. [6] the ADHD/CD and TD groups did not differ on age, but significantly more boys participated than girls, without the gender nevertheless (when added as a covariate) having been reported to exert an effect on emotion recognition. In contrast to Guyer et al. [6] two studies found 7–12-year-old children with ADHD to be less accurate in emotion labelling compared to TD [1, 11]. Corbett and Glidden [1] as well as Pelc et al. [11], differed from Guyer et al. [6] in that younger children participated whereas in Guyer et al. [6] participants were not younger than 12 years of age. In all other experimental studies included in the review, the ADHD and TD groups were age and gender matched.

5.4 Static Versus Dynamic Stimuli

Most studies implicated static stimuli with only the minority having dynamic stimuli in their design [9, 14, 15, 17, 19]. Boakes et al. [9] was the only to have compared static, dynamic-decontextualized and dynamic stimuli with a relevant situational context (dynamic-contextualized stimuli). Surprisingly, although boys with ADHD showed impairments in emotion recognition compared to healthy children, they did not appear to benefit from the increasing number of contextual information. Bal [14] used the Dynamic Affect Recognition Evaluation [69] where stimuli were developed from the Cohn–Kanade Action Unit-Coded Facial Expression Database (Cohn et al. 1999). Participants were presented with morphed images in a video-like format where neutral emotions were transitioning into one of the six basic emotions and children had to label the emotions presented. The authors found that the ADHD group were worse compared to the control group to label anger and disgust. Participants in Ludlow et al. [17] were presented with a series of 28 short video-taped vignettes of trained professionals interacting in everyday situations and portraying one of seven emotions; happy, surprised, neutral, sad, angry, fear and disgust. Children with ADHD were worse overall at recognizing emotions than control participants and specifically the emotions of sadness, anger, fear and surprise. Schwenck et al. [15] assessed emotion recognition via 9-s films of morphed facial expressions and failed to find any differences in emotion recognition between children with ADHD and healthy controls. Despite the stimuli being dynamic in that a neutral facial expression was continuously changed to an emotional expression, it could still be argued that the morphed stimuli lacked ecological validity. The last study to have implicated dynamic stimuli was the genotype study of van Goozen et al. [19] which did not include a control group in their design as the authors aimed to investigate the links between the COMT genotype and aggression in male adolescents with ADHD.

5.5 Differentiation Among Specific Emotion Dimensions

Some studies found a deficient performance for specific emotions while others either did not differentiate among specific emotion dimensions or did not define the emotions investigated. Table 2 presents the emotions examined in each study indicating whether the authors differentiated among specific emotion dimensions in their analyses and the emotions that children with ADHD showed impairments compared to controls. As can be seen from the table below two studies; Downs and Smith [3] and Greenbaum et al. [12], did not define the emotions investigated as Downs and Smith [3] assessed children's theory of mind and Greenbaum et al. [8] participants' affective processing. Four studies did not differentiate among specific emotion dimensions in their analyses [1, 5, 6, 24] namely, Corbett and Glidden [1], Yuill and Lyon [5], Guyer et al. [6] and Rinke et al. [24]. Three studies assessed all 6 emotions [1, 5, 24] and whereas Corbett and Glidden [1] and Yuill and Lyon [5] found significant differences among children with and without ADHD, Guyer et al. [6] and Rinke et al. [24] failed to do so. All four studies implicated static stimuli, with the Corbett and Glidden [1] and Rinke et al. [24] assessing emotion recognition using the Pictures of Facial Affect [32], Yuill and Lyon [5] a non-emotional and emotion matching task and Guyer et al. [6] the DANVA [58].

Most of the studies included in the review investigated all six basic emotions [4, 8, 9, 14, 17, 20, 23], five studies three of the basic emotions [16, 18, 19, 21, 22], three studies examined five basic emotions [7, 10, 15] and three studies four basic emotions [2, 11, 26]. Among the studies that differentiated among specific emotion dimensions in their analyses the most researched emotion was "happiness" closely followed by "anger" and "sadness". Table 3 presents the number of emotions investigated among the studies that differentiated among emotion dimensions and the percentage of studies that found significant differences among children with ADHD and TD.

From the table above it can be inferred that children with ADHD are more frequently reported to be impaired on the emotion of fear as six out of the 13 studies (46%) that assessed fear found deficits on emotion recognition. Anger and surprise follow, with one third of the studies investigating anger (33%) and 28% of the studies investigating surprise, having reported impairments in children the ADHD compared to TD. With regards to happiness only three out of the 19 studies found significant differences among children with ADHD and the control group.

Table 3 Emotions investigated and % of studies that found deficits in ADHD children among the studies that differentiated specific emotion dimensions in their analyses

Emotions investigated	Sadness	Fear	Happiness	Disgust	Surprise	Anger
No. of studies	18	13	19	10	7	18
No. of studies reporting significant differences among children with and without ADHD	4 [2, 11, 17, 21]	6 [2, 4, 7, 9, 17, 26]	3 [2, 8, 21]	2 [9, 14]	2 [8, 17]	6 [7, 11, 14, 16, 17, 21]
% of Studies reporting a significant difference in emotion recognition	22.2	46.2	15.8	20.0	28.6	33.3

With regards to sadness, all four studies that found significant results used differed emotion recognition measures; Cadesky et al. [2] employed the DANVA [58, 11] used a series of emotional facial expressions constructed and validated by Hess and Blairy [44], Ludlow et al. [17] the Emotion Evaluation Test (EET) from The Awareness of Social Inference Test (TASIT) [57, 21] a computerized facial emotion recognition task based on the Cohn- Kanade face database [48]. In DANVA [58], the emotional facial expressions by Hess and Blairy [44] and the emotion recognition task based on the Cohn- Kanade face database [48] static faces are presented while in EET from the TASIT [57] the stimuli are dynamic namely, vignettes of trained professionals interacting in everyday situations. Except for DANVA where stimuli of both adults and children were presented, in all other studies whose measures found significant differences among children with and without ADHD facial expressions of only adults were presented.

The emotion recognition measures used in the studies that found significant dif-ferences among ADHD and TD with regards to fear were the: DANVA [58] in [2], FEEST [88] in [4], facial expressions from the Gur et al. [41] database in Williams et al. [7], FAIT in Baokes et al. [9], EET from TASIT [57] in [17] and Pictures of Facial Affect [32] in Airdrie et al. [26]. All measures implicated static stimuli except for FAIT that implicated static and dynamic and EET from TASIT that implicated dynamic stimuli.

With regards to happiness, three studies found significant differences among the two populations and albeit all of them using static stimuli, they utilized different measures namely, Cadesky et al. [2] the DANVA [58, 8] the FEFA [10, 21] the Cohn Kanade AU-coded Facial Expressions Database [48]. Only two studies found chil-dren with ADHD to be impaired in the emotion recognition of disgust compared to

TD. Both studies utilized dynamic stimuli; Bal et al. [14] used DARE [14] where morphed images were presented in a video like format slowly transitioning into one of the 6 basic emotions [69] and Da Fonseca et al. [10] the FAIT where static, dynamic-decontextualized and dynamic-contextualized stimuli were presented in either a cartoon or a real-life portrayal mode. Noteworthy, is that a third study that investigated disgust (Aspan et al. 2004), [4], found increased sensitivity in the recog-nition of disgust in adolescent boys with ADHD compared to TD boys. The authors assessed emotion recognition in their study via the FEEST [88] where participants had to label the emotions of static stimuli presented on the screen.

Two out of the seven studies that implicated surprise in their design found signif-icant differences; Sinzig et al. [8] via the FEFA [10, 17] via the EET from TASIT [57]. Static and dynamic stimuli were used respectively in the studies. One third of the studies that implicated anger in their analyses found differences among children with and without ADHD. All but two studies used static stimuli; Pelc et al. [11] via the Set of Emotional Facial Stimuli [44, 7] via the Gur et al. [41] facial expressions, Kochel et al. [16] via the KDEF [36, 21] via the Cohn Kanade AU-coded Facial Expressions Database [48]. The two studies that implicated dynamic stimuli were Bal et al. [14] and Ludlow et al. [17] that used the DARE [69] and EET from the TASIT [57] respectively.

In addition to the great variability of measures administered among the studies that found significant results for each emotion, great variability is also observed with regards to the study population. For example, for sadness half of the studies implicated both genders and half only boys, for fear and anger the majority (i.e. four studies) implicated only boys and two studies children of both genders, for happiness out of the three studies that found significant differences among children with and without ADHD two assessed both genders and one only boys.

5.6 Assessing Reaction Time on Emotion Recognition

Among the 25 studies included in the review, seven assessed reaction time; Passarotti et al. [13], Bal [14], Schwenck et al. [15], Kochel et al. [16], Noordermeer et al. [18], Tehrani-Doost et al. [21] and Rinke et al. [24]. Children with ADHD were profoundly slower to recognize angry than neutral facial expressions in Passarotti et al. [13], no differences in reaction time were found between children with ADHD and TD children in Bal [14], Schwenck et al. [15] and Kochel et al. [16] and children with ADHD required more time than TD children to recognize the happy facial expressions in Tehrani-Doost et al. [21]. Whereas in Noordermeer et al. [18] the ADHD + ODD group showed slower mean RTs for correct responses compared with controls indicating difficulties in correctly identifying angry facial emotions, the ADHD-only group did not differ from TD. In Rinke et al. [24] no differences in reaction time were found between the experimental groups. Nevertheless, younger children were faster in their responses than older children indicating along with the finding that younger children were worse in the recognition of anger compared to older children, that the facial emotion recognition is above all an age-dependent function. The relations among reaction time and comorbidity were only assessed in Noordermeer et al. [18] as in Passarotti et al. [13], Bal [14], Schwenck et al. [15], Kochel et al. [16] and Tehrani-Doost et al. [21] children with only ADHD participated. In Rinke et al. [24] out of the 29 participants with ADHD, 2 were diagnosed with comorbid developmental disorder. In summary four studies failed to find any differences in reaction time among children with ADHD and TD, one found children with ADHD to require more time to recognize anger compared to controls [13], one found children with ADHD + ODD to be slower to recognize anger compared to TD [18] and one concluded that ADHD boys were slower in the recognition of happiness compared to controls [21]. Interesting is than in Tehrani-Doost et al. [21] participants were the youngest of the studies that assessed reaction time (8.75, 1.39).

5.7 *The Factor of Comorbidity*

Among the studies included in the literature review, nine [2, 3, 6, 8, 12, 14, 18, 24, 26] implicated children with ADHD and 1 or more comorbid conditions. Nevertheless, not all of them controlled for the factor of comorbidity on emotion recognition i.e. comparing children with only ADHD and ADHD + 1 comorbidity. Taking a closer look Cadesky et al. [2] compared a group of children only with ADHD and with ADHD + CD, Sinzig et al. [8] compared children with ADHD, ASD, Autism + ADHD, Nordermeer et al. [18] implicated children with ADHD, ADHD + ODD and Airdrie et al. [26] children with ADHD and ADHD + CD. Among these studies that controlled for the factor of comorbidity in their analyses, Cadesky et al. [2] found that TD children outperformed the groups of children with ADHD only and CD only, whereas children with the combined symptomatology (ADHD and CD) did not differ from TD children. In contrast Airdrie et al. [26] found children with the combined symptomatology (ADHD + CD) to be less accurate in the recognition of fear than both children with ADHD and TD and children with ADHD to be performing similarly to TD in the recognition of fear. Both studies used static stimuli which have been argued to lack ecological validity. Sinzig et al. [8] found children suffering from ADHD and ADHD + ASD when compared to TD children to be impaired on both facial affect recognition and recognition of emotion from eye-pairs. Furthermore, children with ADHD + ASD were worse in the recognition of happiness and surprise from eye-pairs and faces respectively, when compared to TD children and children with ASD and children with ADHD scored lower on the recognition of happiness (eye-pairs) when compared to TD children.

When it comes to autism, Downs and Smith [3] studied emotion recognition on the notion of the theory of mind and found the group of children with ADHD and ODD to have performed worse than healthy controls. It is important to mention that the authors did to implicate a group of children with ADHD only in their study. Despite Guyer et al. [6] implicating 18 children with ADHD, 7 with Conduct Disorder

(CD) and 10 with ADHD + CD these three groups were treated as one to maximize statistical power and as a result of the preliminary analyses conducted which indicated similar mean scores among the three groups. Furthermore, whereas Greenbaum et al. [12] and Bal [14] report one third and more than a third (respectively) of children with ADHD having 1 or more comorbidities, no more information is provided as to which these comorbidities were, with the comorbidities hence not taken into account in their analyses. Likewise, despite only two of the 29 children with ADHD having been diagnosed with comorbid developmental disorder in Rinke et al. [24] no further information is provided as to whether this factor influenced the results of the study.

5.8 Neural Correlate of Emotion Recognition in ADHD

Functional neuroimaging techniques and event-related potential (ERP) studies have identified alterations in the activation and inhibition of several brain areas in children and adolescents with ADHD during the execution of tasks requiring facial emotion recognition. While children with ADHD did not differ from TD children in the accuracy of emotion recognition in Passarotti et al. [13], alterations in the activation of brain regions were highlighted; relative to TD children, children with ADHD exhibited greater activation in DLPFC (increased activity with positive emotional chal-lenge in cortico-subcortical circuitry) and reduced activation in ventral and medial PFC, pregenual ACC, striatum and temporo-parietal regions (decreased activity with negative emotional challenge). In the event-related potential study of Kochel et al. [16] boys with ADHD made more recognition errors for anger than TD boys and longer reaction times were required for the emotional compared to the neutral task, with the longest RT times being recorded for anger. Children with ADHD relative to controls displayed a severe impairment in response inhibition toward anger cues, which was accompanied by a reduced P300 amplitude. The control group showed a P300 differentiation of the affective categories that was absent in the ADHD group. Williams et al. [7] observed a significant reduction in accipital activity during the early perceptual analysis of emotional expressions (within 120 ms) followed by an exaggeration of activity associated with structural encoding (120–220 ms) and subsequent reduction and slowing of temporal brain activity subserving context processing (300–400 ms). Sarraf Razavi et al. [22] found ADHD children to have a significant reduction in the gamma band activity when compared to TD children in occipital site and a significant decrease for happiness and anger in the left and right occipital, respectively.

6 Discussion

ADHD is a neurodevelopmental disorder affecting people of all ages and of both genders. The symptoms of ADHD begin in childhood (usually between the ages of

3 to 6), and for about half of the children, the symptoms continue into adolescence and adulthood. School-aged children with ADHD have been reported to suffer from social and emotional deficits.

Studies on facial emotion recognition in children and adolescents with ADHD focused mainly on the recognition accuracy of facial emotions, showing inconsistent results and a heterogenous use of measures. This review identified 25 studies to have implicated individuals under the age of 18 diagnosed with ADHD according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders. The male sample exceeded the female and most studies used groups comparable on age and gender. Our literature review focusing on the ADHD population cannot support McClure [56] who conducted a meta-analysis to examine sex differences in the development of facial expression recognition, and provided clear evidence for a small, although robust female advantage in emotion expression recognition over the developmental period (from infancy into adolescence). One could argue that this could be the result of the absence of gender differences on emotion recognition in ADHD. One study in this literature review, Guyer et al. [6] argued for developmental differences in emotion recognition in ADHD, a finding concurrent with literature arguing that the recognition of emotion expression does not emerge as one specific stage in development rather gradually over time [25, 84]. In contrast to Corbett and Glidden [1] and Pelc et al. [11] who found 7–12 year olds with ADHD to be less accurate at emotion labelling than TD children, in Guyer et al. [6], participants were older than 12 years of age, arguing that preadolescent children (participating in [1, 11]) could have greater difficulties labelling facial emotions than do older children with ADHD.

With regards to the stimuli used to assess the emotion recognition skills of children with ADHD five studies implicated dynamic stimuli [9, 14, 15, 17, 19]. All studies used different tasks to assess emotion recognition. As a result of van Goozen et al. [19] being a genotype study a control group was not implicated so comparisons among the two groups were not feasible. Among those that were experimental and implicated a control group and dynamic stimuli, two found significant differences between children with ADHD and TD children; Bal et al. [14] and Ludlow et al. [17]. In Bal et al. [14] more than half of the ADHD participants were also diagnosed with a comorbidity, both males and females participated, and the DARE task was to assess emotion recognition. Children with ADHD were impaired in the recognition of anger and disgust but not in the recognition of fear, happiness, sadness and surprise. In contrast in the study of Ludlow et al. [17] only boys with ADHD participated, the EET from the TASIT was employed [57] and TD children performed significantly better in the recognition of anger, surprise, sadness and fear. It should be mentioned nevertheless that whereas only boys with ADHD participated in Ludlow et al. [17], the control group was composed of both boys and girls while gender was not added as a covariate. Boakes et al. [9] and Schwenck et al. [15] employed the Facial Affect Interpretation Task (FAIT) and Karolinska Directed Emotional Faces [55] respectively. In Boakes et al. [9] children only with ADHD and without any comorbidities participated, while in Schwenck et al. [15] both boys and girls with only ADHD took part. From the present literature review we can hence say that despite static stimuli having been argued to lack ecological validity, the studies implicating dynamic stimuli in this review have not produced more conclusive results with regards to the emotion recognition skills of children with ADHD.

Striking is the fact that none of the studies included in the review assessed whether the type of stimuli administered i.e. stimuli gender (males or females) and age (children or adults) had an effect on the accuracy of emotion recognition. This factor is crucial to be taken in future studies into account as it will provide the opportunity for more in depth results when it comes to the accuracy of emotion recognition.

A wide range of measures have been employed to assess affect recognition. Among the 25 studies included in the review, 18 different measures were used. Taking into account the great variability of measures administered, this section will discuss the most commonly used measures as per the systematic review; Pictures of Facial Affect [32], DANVA [63], Karolinska Directed Emotional Faces database (KDEF) [55], Computer-based Frankfurt Test for Facial Affect Recognition [10], faces by Gur et al. [41] and the Cohn-Kanade Facial Expressions Database [48].

The most frequently used measure was the Pictures of Facial Affect [32] which was utilized by four studies included in the review (either in the original or computerized and extended version). In the pictures of facial affect every model was photographed neutrally and showed one of the seven basic emotions: happiness, anger, fear, surprise, sadness, disgust, and contempt. Using the Facial Action Coding System (FACS; Ekman et al. 2002), researchers were able to produce pictures of standardized facial expressions that were intended to represent "prototypical displays" of emotions. While, the Pictures of Facial Affect have been extensively used in research, it is important to consider the factor of the faces being non-contemporary and presented in black and white format (Fig. 2).

One of the most elaborate sets which is the original Karolinska Directed Emotional Faces database (KDEF) consists of a total of 490 JPEG pictures showing 70 individuals (35 women and 35 men) displaying 7 different emotional expressions (Angry, Fearful, Disgusted, Sad, Happy, Surprised, and Neutral). Each expression is viewed from 5 different angles and all the individuals portraying the emotions were trained amateur actors between 20 and 30 years of age. Researchers interested in this database can freely select pictures as a function of (a combination of) several parameters: sex of the expressor, quality of the emotional expression per expressor, hit rate, intensity, and/or arousal. Despite the KDEF having scored high on the validity and reliability measures with the mean biased hit rate of 72% being comparable with other validation studies [33], one of the most critical limitations is the dataset being limited to adult stimuli and omitting to include any child stimuli as well (Fig. 3).

The DANVA [63] stimuli are faces of adults and children displaying one of four emotional expressions (happiness, sadness, anger, and fear) that vary between pictures in their intensity levels with the use of variable intensity levels corresponding to item difficulty. The researchers created facial expression stimuli by reading participants a vignette and then photographing the participants as they produced a facial

Fig. 2 Example of each emotion of the Pictures of Facial Affect [32]

Fig. 3 Example of each emotion (Angry, Fearful, Disgusted, Happy, Sad, Surprised, and Neutral) of the KDEF stimulus set

expression that was appropriate for the vignette. The test can provide adequate per-formance scores for emotion recognition ability across a broad range of facial char-acteristics relying on affect naming. DANVA nevertheless only includes pictures for four out of the six basic emotions.

The computer-based Frankfurt Test for Facial Affect Recognition [10] uses the cross-cultural concept of the seven fundamental affective states by Ekman, Friesen, and Ellsworth (1972) and comprise a series of 50 items with black and white pictures presenting basic emotions for faces (face test) and 40 items for eyes (eyes test). Each picture is shown on the computer screen separately with all six emotions written on the side of the picture as an answer option. It is important to mention that some of the photographs included were from the pictures of facial affect by Ekman & Friesen [32]. Whereas the psychometric properties of FEFA having been reported to be excellent (Bolte and Poustka 2003) a striking limitation is the pictures being presented in black and white hence lacking ecological validity and depicting only adults.

The 3D faces developed by Gur et al. [41] were developed on the notion that facial expressions of emotion are increasingly being used in neuroscience as stimuli for studying hemispheric specialization and as probes for functional imaging for face and emotion processing. The orientation of the 2-dimensional face stimuli is fixed and poorly suited for examining asymmetries, where the actors are of a restricted age range and usually pose. The 3-dimenionional faces by Gur et al. [41] were used in the two neuroimaging studies of the review: an fMRI and an ERP study. The 3D images were acquired and reconstructed by adult actors and actresses expressing the 6 basic emotions as well as neutral expressions.

The Cohn-Kanade Facial Expressions Database [48] includes 2105 digitized image sequences from 182 adults between the ages of 18–50 years of age (69% female and 31% male) of varying ethnicity, performing multiple tokens of most pri-mary FACS action units representing happiness, surprise, sadness, disgust, anger, and fear. Despite the database being one of the most comprehensive ones for com-parative studies of facial expression analysis, two limitations are: (1) the absence of child stimuli and (2) the lack of spontaneous expressions taking into account that deliberate and spontaneous expressions have different appearance and timing (Fig. 4).

When evaluating the emotion recognition accuracy of children with ADHD it is important to consider how many and which of the basic emotions were investigated. Most of the studies included in the review investigated all six basic emotions [4, 8, 9, 14, 17, 20, 23] with the most researched emotion being happiness followed by anger, sadness and fear. Another great variability identified in the review was that despite the majority of studies having differentiated among specific emotion dimensions in their analyses, two did not define the emotions investigated; Downs and Smith [3] and Greenbaum et al. [12], and four studies did not differentiate among specific emotion dimensions in their analyses; Corbett and Glidden [1], Yuill and Lyon [5], Guyer et al. [6] and Rinke et al. [24].

Fig. 4 Frontal and 30-degree to the side views available in the database

When it comes to comorbidities, albeit nine out of the 25 studies included in the review having implicated children with ADHD and 1 or more comorbid conditions only four controlled for the factor of comorbidity in their analyses while also including a control group; Cadesky et al. [2], Sinzig et al. [8], Nordermeer et al. [18], and Airdrie et al. [26]. Different comorbidities were nevertheless assessed as in Sinzig et al. [8] ASD and in Nordermeer et al. [18] ODD. Despite Cadesky et al. [2] and Airdrie et al. [26] both implicating children with CD, the two studies found conflicting results. Whereas both studies implicated static stimuli and studied the same emotions (Happiness, Fear, Anger, Sadness) Cadesky et al. [2] employed the DANVA [63, 26] the Pictures of Facial Affect [32]. An additional difference among the two studies was that children in Aidrie et al. [26] were older (9.3, 1.5) than Aidrie's et al. [26] (14.20, 2.09). Literature suggests that ADHD rarely occurs in isolation being highly concurrent with ASD; according to Davis and Kollins [22] more than two-thirds of individuals with ADHD show features of ASD), there is a comorbidity of 60% with ODD and a prevalence of 16–20% with CD [85]. Whereas the presence of comorbid disorders may pose a potential explanation for the reported difficulties in face recognition in children and adolescents with ADHD, research controlling for the factor of comorbidity in the analyses while also including a control group is sparse.

Despite a web-based search on emotion recognition in ADHD will elicit hun-dreds of studies, one cannot concretely say in which factors do children with ADHD differ from TD children. Literature on emotion recognition in ADHD has produced mixed findings, a result that can be partly attributed to the great variability of studies employed in the investigation of emotion recognition in ADHD and the complexity of facial emotion recognition in this psychiatric population. While, several factors have been carefully taken into consideration in the design of the studies included in the review, one cannot but wonder whether the studies' participants were undertak-ing therapies other than pharmacotherapy (i.e. occupational therapy, psychotherapy) with aim to tackle the social and emotional deficits of ADHD and whether these therapeutic methods had an impact on the studies' results.

Acknowledgements The research leading to these results has received funding from the EU H2020 research and innovation program under grant agreement N. 769872 (EMPATHIC) and N. 823907 (MENHIR), the project SIROBOTICS that received funding from Italian MIUR, PNR 2015– 2020, D.D. 1735, 13/07/ 2017, and the project ANDROIDS that received funding from Università della Campania "Luigi Vanvitelli" inside the program V:ALERE 2019, funded with D.R. 906 del 4/10/2019, prot. n. 157264,17/10/2019.

References

1. Airdrie, J.N., Langley, K., Thapar, A., van Goozen, S.H.M.: AC. J Am Acad Child Adolesc Psychiatry **57**(8), 561–570 (2018). http://doi.org/10.1016/j.jaac.2018.04.016
2. Arsenio, W., Cooperman, S., Lover, A.: Affective predictors of preschoolers' aggression and peer acceptance: direct and indirect effects. Develop. Psychol. **36**(4), 438–448 (2000). https://doi.org/10.1037/0012-1649.36.4.438. [PubMed: 10902696]

3. Aspan, N., Bozsik, C., Gadoros, J., Nagy, P., Inantsy-Pap, J., Vida, P., Halasz, J.: Emotion recognition pattern in adolescent boys with attention-deficit/hyperactivity disorder. BioMed Res. Int. (2014). http://dx.doi.org/10.1155/2014/761340
4. Bal, Elgziz: *Emotion Recognition and Social Behaviors in Children with Attention-Deficit/Hyperactivity Disorder* (Published doctoral dissertation). University of Illinois at Chicago, Chicago, Illinois (2011)
5. Barkley, R.A.: Behavioral inhibition, sustained attention, an executive functions: constructing a unified theory of ADHD. Psychol. Bull. **121**, 65–94 (1997)
6. Baum, K.M., Nowicki, S. Jr.: Perception of emotion: measuring decoding accuracy of adult prosodic cues varying in intensity. J. Nonverbal Behav. **22**, 89–107 (1998)
7. Berggren, S., Engström, A.-C., Bölte, S.: Facial affect recognition in autism, ADHD and typical development. Cognit. Neuropsychiatry **21**(3), 213–227 (2016). http://doi.org/10.1080/ 13546805.2016.1171205
8. Blair, R.J.R.: Facial expressions, their communicatory functions and neuro-cognitive substrates. Philos. Trans. R. Soc. B **358**, 561–572 (2003). http://doi.org/10.1098/rstb.2002.1220
9. Boakes, J., Chapman, E., Houghton, S., West, J.: Facial interpretation in boys with attention deficit/hyperactivity disorder. Child Neuropsychol. **14**, 82–96 (2008)
10. Bolte, S., Feineis-Matthews, Sabine, Leber, S., Dierks, T., Hubl, D., Poustka, F.: The development and evaluation of a computer-based program to test and teach the recognition of facial affect. Int. J. Circumpolar Health **61**(2), 61–68 (2002). https://doi.org/10.3402/ijch.v61i0. 17503
11. Bora, E., Pantelis, C.: Meta-analysis of social cognition in attention-deficit/ hyperactivity disorder (ADHD): comparison with healthy controls and autistic spectrum disorder. Psychol. Med. **46**, 699–716 (2016). http://doi.org/10.1017/S0033291715002573
12. Boyatzis, C.J., Chazan, E., Ting, C.Z.: Preschool children's decoding of facial emotions. J. Genet. Psychol. **154**(3), 375–382 (1993). http://doi.org/10.1080/00221325.1993.10532190
13. Bruce, V., Campbell, R.N., Doherty-Sneddon, G., Langton, S., McAuley, S., Wright, R.: Testing face processing skills in children. Br. J. Dev. Psychol. **18**, 319–333 (2000). http://doi.org/10. 1348/026151000165715
14. Cadesky, E.B., Mota, V.L., Schachar, R.J.: Beyond words: how do children with ADHD and/or conduct problems process nonverbal information about affect? J. Am. Acad. Child Adolesc. Psychiatry **39**(9), 1160–1167 (2000). http://doi.org/10.1097/00004583-200009000-00016
15. Caspi, A., Taylor, A., Moffitt, T.E., Plomin, R.: Neighborhood deprivation affects children's mental health: environmental risks identified in a genetic design. Sage J. **11**(20), 338–342 (2000). https://doi.org/10.1111/1467-9280.00267
16. Corbett, B., Glidden, H.: Processing affective stimuli in children with attention-deficit hyper-activity disorder. Child Neuropsychol. **6**(2), 144–155 (2000). http://doi.org/10.1076/chin.6.2. 144.7056
17. Corcoran, C.M., Keilp, J.G., Kayser, J., Klim, C., Butler, P.D., Bruder, G.E., … Javitt, D.C.: Emotion recognition deficits as predictors of transition in individuals at clinical high risk for schizophrenia: a neurodevelopmental perspective. Psychol. Med. **45**(14), 2959–2973 (2015). http://doi.org/10.1017/S00332917150009024
18. Coy, K., Speliz, M.L., DeKlyen, M., Jones, K.: Social-cognitive processes in preschool boys with and without oppositional defiant disorder. J. Abnormal Child Psychol. **229**(2) (2001). http://doi.org/107–119.10.1023/a:1005279828676 [PubMed: 11321626]
19. Da Fonseca, D., Sequier, V., Santos, A., Poinso, F., Deruelle, C.: Emotion understanding in children with ADHD. Child Psychiatry Human Dev. **40**, 111–121 (2009)
20. Dadds, M.R., Cauchi, A.J., Wimalaweera, S., Hawes, D.J., Brennan, J.: Outcomes, moderators, and mediators of empathic-emotion recognition training for complex conduct problems in childhood. Psychiatry Res. **199**(3), 201–207 (2012). https://doi.org/10.1016/j.psychres.2012. 04.03
21. Dalili, M.N., Penton-Voak, I.S., Harmer, C.J., Munafò, M.R.: Meta-analysis of emotion recog-nition deficits in major depressive disorder. Psychol. Med. **45**(6), 1135–1144 (2015). https:// doi.org/10.1017/S0033291714002591

22. Davis, N.O., Kollins, S.: Treatment for co-occurring attention deficit/hyperactivity disorder and autism spectrum disorder. Neurotherapeutics **9**(3), 518–530 (2012)
23. De Sonneville, L.M.J.: Amsterdamse neuropsychologische taken: wetenschappelijke en klinische toepassingen. J. Neuropsychol. **1**, 27–41 (2005)
24. De Sonneville, L.M.J., Verschoor, C.A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., Vranken, M.: Facial identity and facial emotions: speed, accuracy, and processing strategies in children and adults. J. Clin. Exp. Neuropsychol. (Neuropsychol. Dev. Cogn. Sec. A) **24**(2), 200–213 (2002). http://doi.org/10.1076/jcen.24.2.200.989
25. De Sonneville, L.M.J., Verschoor, C.A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., Vranken, M.: Facial identity and facial emotions: speed, accuracy, and processing strategies in children and adults. J. Clin. Exp. Neuropsychol. (Neuropsychol. Dev. Cogn. Sect. A) **24**(2), 200–213 (2002). http://doi.org/10.1076/jcen.24.2.200.989
26. Denham, S.A.: Emotional Development in Young Children. Guilford Press, New York, London (1998)
27. Denham, S.A.: Social-emotional competence as a support for school readiness: what is it and how do we assess it? Early Edu. Dev. **17**, 57–89 (2006). https://doi.org/10.1207/s15566935eed1701_4
28. Downs, A., Smith, T.: Emotional understanding, cooperation, and social behaviour in high-functioning children with autism? J. Autism Dev. Dis. **34**, 625–635 (2004)
29. DuPaul, G.J., Volpe, R.J., Jitendra, A.K., Lutz, J.G., Lorah, K.S., Gruber, R.: Elementary school students with AD/HD: predictors of academic achievement. J. Sch. Psychol. **42**(4), 285–301 (2004). https://doi.org/10.1016/j.jsp.2004.05.001
30. Ekman, P.: Universals and cultural differences in facial expressions of emotion. In: Cole J. (ed.) Nebraska Symposium on Motivation, 1971, vol. 19, pp. 207–282. University of Nebraska Press: Lincoln (1972)
31. Ekman, P.: Facial expression and emotion. Am. Psychol. **48**(4), 384–392 (1992)
32. Ekman, P., Friesen, W.V.: Pictures of facial affect. Palo Alto. California: Consulting Psychol-ogists Press (1976)
33. Elfenbein, H.A., Mandal, M.K., Ambady, N., Harizuka, S., Kumar, S.: Hemifacial differences in the in-group advantage in emotion recognition. Cognit. Emot. **18**, 613–629 (2004)
34. Esposito, A., Esposito, A.M., Vogel, C.: Needs and challenges in human computer interaction for processing social emotional information. Pattern Rec. Lett. **66**, 41–51 (2015)
35. Fayyad, J., De Graaf, R., Kessler, R., Alonso, J., Angermeyer, M., Demyttenaere, K.,… Lepine, J.P.: Cross-national prevalence and correlates of adult attention-deficit hyperactivity disorder. Br. J. Psychiatry **190**(5), 402–409 (2007)
36. Goeleven, E., De Raedt, R., Leyman, L., Verschuere, B.: The karolinska directed emotional faces: a validation study. Cognit. Emotion **22**(6), 1094–1118 (2008)
37. Gosselin, P.: Le décodage de l'expression faciale des émotions au cours de l'enfance (The decoding of facial expressions of emotions during childhood). Can. Psychol. **46**, 126–138 (2005)
38. Gosselin, P., Larocque, C.: Facial morphology and children's categorization of facial expressions of emotions: a comparison between Asian and Caucasian faces. J. Genet. Psychol. **161**, 346–358 (2000)
39. Green, M.F., Kern, R.S., Robertson, M.J., Sergi, M.J., Kee, K.S.: Relevance of neurocognitive deficits for functional outcome in schizophrenia. In: Sharma, T., Harvey, P. (eds.) Cognition in Schizophrenia: Impairments, Importance, and Treatment Strategies, pp. 178–192. Oxford University Press, New York (2000)
40. Greenbaum, R.L., Stevens, S.A., Nash, K., Koren, G., Rovet, J., Form, T.R., … Program, M.: Social cognitive and emotion processing abilities of children with fetal alcohol spectrum disorders. Hyperact. Disord. **33**(10), 1656–1670 (2009). https://doi.org/10.1111/j.1530-0277. 2009.01003.x
41. Gur, R.C., Sara, R., Hagendoorn, M., Marom, O., Hughett, P., Macy, L.,… Gur, R.E: A method for obtaining 3-dimensional facial expressions and its standardization for use in neurocognitive studies. J. Neurosci. Methods **115**(2), 137–143 (2002)

42. Guyer, A.E., McClure, E.B., Adler, A.D., Brotman, M.A., Rich, B.A., Kimes, A.S., Pine, D.S., Ernst, M., Leibenluft, E.: Specificity of facial expression labeling deficits in childhood psychopathology. Psychol. Fac. Public. **119** (2009)
43. Herba, C., Phillips, M.: Annotation: Development of facial expression recognition from childhood to adolescence: Behavioural and neurological perspectives. J. Child Psychol. Psychiatry **45**(7), 1185–1198 (2004). https://doi.org/10.1111/j.1469-7610.2004.00316.x
44. Hess, U., Blairy, S.: Set of emotional facial stimuli. Department of Psychology, University of Quebec at Montreal, Montreal, Canada (1995)
45. Howlin, P., Baron-Cohen, S., Hadwin, J.: Teaching Children with Autism to Mind-Read: A Practical Guide. Wiley, West Sussex (1999)
46. Hoza, B., Mrug, S., Gerdes, A.C., Hinshaw, S.P., Bukowski, W.M., Gold, J.A., et al.: What aspects of peer relationships are impaired in children with attention-deficit/hyperactivity disorder? J. Cons. Clin. Psychol. **73**, 411–423 (2005). https://doi.org/10.1037/0022-006X.73.3.411
47. Jusyte, A., Gulewitsch, M.D., Schönenberg, M.: Recognition of peer emotions in children with ADHD: evidence from an animated facial expressions task. Psychiatry Res. **258**(2017), 351–357 (2017)
48. Kanade, T., Cohn, J.F., Yingli Tian.: Comprehensive database for facial expression analysis. Paper presented at the 4th IEEE International Conference on Automatic Face and Gesture Recognition (Cat. No. PR00580). Grenoble, France, 28–30 March 2000 (2000). http://doi.org/ 10.1109/afgr.2000.840611
49. Kara, H., Bodur, S., Çetinkaya, M., Kara, K., Tulaci, O.D.: Assessment of relationship between comorbid oppositional defiant disorder and recognition of emotional facial expressions in chil-dren with attention-deficit/hyperactivity disorder. Psychiatry Clin. Psychopharmacol. **27**(4), 329–336 (2017). https://doi.org/10.1080/24750573.2017.1367566
50. Kochel, A., Leutgeb, V., Schienle, A.: Disrupted response inhibition toward facial anger cues in children with Attention-Deficit Hyperactivity Disorder (ADHD): an event-related potential study. J. Child Neurol. **29**(4), 459–468 (2014)
51. Lai, Z., Hughes, S., Shapiro, E.: Manual for the tests of affective processing (MNTAP). University of Minnesota, MN (1991)
52. Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D.H., Hawk, S.T., van Knippenberg, A.: Presentation and validation of the radboud faces database. Cognit. Emotion **24**(8), 1377–1388 (2010). https://doi.org/10.1080/02699930903485076
53. Lee, S.S., Falk, A.E., Aguirre, V.P.: Association of comorbid anxiety with social functioning in school-age children with and without attention-deficit/hyperactivity disorder (ADHD). Psychiatry Res. **197**, 90–96 (2012). https://doi.org/10.1016/j.psychres.2012.01.018
54. Ludlow, A., Garrood, A., Lawrence, K., Gutierrez, R.: Emotion recognition from dynamic emotional displays in children with ADHD. J. Soc. Clin. Psychol. **33**(5), 413–427 (2014). https://doi.org/10.1521/jscp.2014.33.5.413
55. Lundqvist, D., Flykt, A., Öhman, A.: The Karolinska directed emotional faces (KDEF). CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet **91**, 630 (1998)
56. McClure, E.B.: A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents. Psychol. Bull. **126**(3), 424–453 (2000). http://doi.org/10.1037/0033-2909.126.3.424
57. McDonald, S., Flanagan, S., Rollins, J.: The Awareness of Social Inference Test. Thames Valley Test Company Limited, Suffolk: England (2002)
58. Maxim, L.A., Nowicki, S.J.: Developmental association between nonverbal ability and social competence. Phil. Soc. Psychol. **2**(10), 745–758 (2003)
59. Miller, A., Gouley, K., Seifer, R., Zakriski, A., Eguia, M., Vergnani, M.: Emotion knowledge skills in low- income elementary school children: associations with social status and peer experiences. Soc. Dev. **14**(4), 637–651 (2005). https://doi.org/10.1111/j.1467-9507.2005. 00321.x

60. Mondloch, C.J., Geldart, S., Maurer, D., Le Grand, R.: Developmental changes in face processing skills. J. Exp. Child Psychol. **86**, 67–84 (2003)
61. Mrug, S., Molina, B. S., Hoza, B., Gerdes, A. C., Hinshaw, S. P., Hechtman, L., & Arnold, L. E. (2012). Peer rejection and friendships in children with attention-deficit/hyperactivity disorder: Contributions to long-term outcomes. *Journal of abnormal child psychology, 40*(6), 1013-1026. http://doi.org/10.1007/s10802-012-9610-2
62. Noordermeer, S.D., Luman, M., Buitelaar, J.K., Hartman, C.A., Hoekstra, P.J., Franke, B., … Oosterlaan, J.: Neurocognitive deficits in attention-deficit/hyperactivity disorder with and without comorbid oppositional defiant disorder. J. Att. Disorde, 1–13 (2015). http://doi.org/10. 1177/1087054715606216
63. Nowicki Jr., S., Duke, M.P.: Individual differences in the nonverbal communication of affect: the diagnostic analysis of nonverbal accuracy scale. J. Nonverbal Behav. **18**, 9–35 (1994)
64. Nowicki Jr., S., Carton, J.: Measuring emotional intensity from facial expressions: the DANVAFACES 2. J. Soc. Psychol. **133**, 749–750 (1993)
65. Passarotti, A.M., Sweeney, J.A., Pavuluri, M.N.: Emotion processing influences working memory circuits in pediatric bipolar disorder and attention deficit hyperactivity disorder. J. Am. Acad. Child Adolesc. Psychiatry **49**(10), 1064–1080 (2010). http://doi.org/10.1016/j.jaac. 2010.07.009
66. Pelc, K., Kornreich, C., Foisy, M.-L., Dan, B.: Recognition of emotional facial expressions inattention-deficit hyperactivity disorder. Pediatr. Neurol. **35**, 93–97 (2006). https://doi.org/10. 1016/j.pediatrneurol.2006.01.014
67. Pochon, R., Declercq, C.: Emotion recognition by children with down syndrome: a longitudinal study. J. Int. Devel. Dis. **38**, 332–343 (2013). https://doi.org/10.3109/13668250.2013.826346
68. Polanczyk, G., De Lima, M.S., Horta, B.L., Biederman, J., Rohde, L.A.: The worldwide prevalence of ADHD: a systematic review and metaregression analysis. Am. J. Psychiatry **164**(6), 942–948 (2007)
69. Porges, S.W., Cohn, J.F., Bal, E., Lamb, D.: The Dynamic Affect Recognition Evaluation [Computer software]. Brain-Body Center, University of Illinois at Chicago, Chicago, IL (2007)
70. Posamentier, M.T.: Processing faces and facial expressions. Neuropsychol. Rev. **13**(3) (2003). http://dx.doi.org/1040-7308/03/0900-0113
71. Raver, C.C., Garner, P.W., Smith-Donald, R.: The roles of emotion regulation and emotion knowledge for children's academic readiness. In: Pianta, R.C., Cox, M.J., Snow, K.L. (eds.) School Readiness and the Transition to Kindergarten in the Era of Accountability, pp. 121–147. Paul H Brookes Publishing, Baltimore, MD (2006)
72. Rinke, L., Candrian, G., Loher, S., Blunck, A., Mueller, A., Jäncke, L.: Facial emotion recognition deficits in children with and without attention deficit hyperactivity disorder: a behavioral and neurophysiological approach. NeuroReport **28**(14), 917–921 (2017). https://doi.org/10. 1097/WNR.0000000000000858
73. Romani, M., Vigliante, M., Faedda, N., Rossetti, S., Pezzuti, L., Guidetti, V., Cardona, F.: Face memory and face recognition in children and adolescents with attention deficit hyperactivity disorder: a systematic review. Neurosci. Biobehav. Rev. **89**, 1–12 (2018)
74. Sarraf Razavi, M., Tehranidoost, M., Ghassemi, F., Purabassi, P., Taymourtash, A.: Emotional face recognition in children with attention deficit/hyperactivity disorder: evidence from event related gamma oscillation. Basic Clin. Neurosci. **8**(5), 419–426 (2017). https://doi.org/10. 18869/NIRP.BCN.8.5.419
75. Schultz, D., Izard, C.E., Ackerman, B.P.: Children's anger attribution bias: relations to family environment and social adjustment. Soc. Dev. **9**(3), 284–301 (2000). https://doi.org/10.1111/ 1467-9507.00126
76. Schwenck, C., Schneider, T., Schreckenbach, J., Zenglein, Y., Gensthaler, A., Taurines, R.,… Romanos, M.: Emotion recognition in children and adolescents with attention-deficit/hyperactivity disorder (ADHD). ADHD Atten. Def. Hyperact. Disord. **5**(3), 295–302 (2013)
77. Sinzig, J., Morsch, D., Lehmkuhl, G.: Do hyperactivity, impulsivity and inattention have an impact on the ability of facial affect recognition in children with autism and ADHD? Eur. Child Adolesc. Psychiatry **17**, 63–72 (2008). https://doi.org/10.1007/s00787-007-0637-9

78. Southam-Gerow, M.A., Kendall, P.C.: Emotion regulation and understanding. Imp. Child Psychopathol. Ther. **22**, 189–222 (2002)
79. Sully, K., Sonuga-Barke., E., Fairchild, G.: The familial basis of facial emotion recognition deficits in adolescents with conduct disorder and their unaffected relatives. Psychol. Med. **45**, 1–11 (2015). http://doi.org/10.1017/S0033291714003080
80. Tehrani-Doost, M., Noorazar, G., Shahrivar, Z., Banaraki, A.K., Beigi, P.F., Noorian, N.: Is emotion recognition related to core symptoms of childhood ADHD? J. Can. Acad. Child Adolesc. Psychiatry **26**(1), 31–38 (2017)
81. Tonks, J., Williams, W.H.U.W., Frampton, I.A.N., Yates, P., Slater, A.: Assessing emotion recognition in 9–15-years olds: Preliminary analysis of abilities in reading emotion from faces, voices and eyes, **21**(June), 623–629 (2007). https://doi.org/10.1080/02699050701426865
82. Uekermann, J.1., Kraemer. M., Abdel-Hamid, M., Schimmelmann, B.G., Hebebrand, J., Daum, I., Wiltfang, J., Kis, B.: Social cognition in attention-deficit hyperactivity disorder (ADHD). Neurosci. Biobehav. Rev. **34**, 734–743 (2010). http://doi.org/10.1016/j.neubiorev.2009.10.009
83. van Goozen, S.H.M., Langley, K., Langley, K., Northover, C., Hubble, K., Rubia, K.,… Thapar, A.: Identifying mechanisms that underlie links between COMT genotype and aggression in male adolescents with ADHD (2016). http://dx.doi.org/10.1111/jcpp.12464
84. Vicari, S., Reilly, J.S., Pasqualetti, P., Vizzotto, A., Caltagirone, C.: Recognition of facial expressions of emotions in school-age children: the intersection of perceptual and semantic categories. Acta Paediatr. **89**(7), 836–845 (2000). http://doi.org/10.1111/j.1651-2227.2000.tb00392.x
85. Villodas, M.T., Pfiffner, L.J., McBurnett, K.: Prevention of serious conduct problems in youth with attention deficit/hyperactivity disorder. Exp. Rev. Neurother. **12**(10), 1253–1263 (2012)
86. Willcutt, E.G.: The prevalence of DSM-IV attention-deficit/hyperactivity disorder: a meta-analytic review. Neurotherapeutics **9**, 490–499 (2012)
87. Williams, L.M., Hermens, D.F., Palmer, D., Kohn, M., Clarke, S., Keage, H.,… Gordon, E: Misinterpreting emotional expressions in attention-deficit/hyperactivity disorder: evidence for a neural marker and stimulant effects. Biologic. Psychiatry **63**(10), 917–926 (2008)
88. Young, A., Perrett, D., Calder, A.J., Sprengelmeyer, R., Ekman, P.: Facial expressions of emotion-stimuli and tests (FEEST). Thames Valley Test Company, Bury St. Edmunds, UK (2002)
89. Yuill, N., Lyon, J.: Selective difficulty in recognising facial expressions of emotion in boys with ADHD: general performance impairments or specific problems in social cognition? Euro. Child Adolesc. Psychiatry **16**(6), 398–404 (2007). http://doi.org/10.1007/s00787-007-0612-5